# ENGINEERING:

## An Illustrated Weekly Journal.

*EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.*

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C. 2

VOL. CVIII.—No. 2803.] *LONDON: FRIDAY, SEPTEMBER 19, 1919.* [*Registered at the General Post Office as a Newspaper.*] [PRICE...9d. BY INLAND POST ... 11d.



**Aveling & Porter, Ltd.,**
ROCHESTER, KENT,
and 73, CANNON STREET, LONDON.
STEAM ROLLERS. ROAD LOCOMOTIVES.
STRAM CULTIVATING MACHINERY.
STEAM WAGONS. TRACTORS.
CEMENT-MAKING MACHINERY. 7667

**A. G. Mumford, Ltd.,**
CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches, BOILER FEED PUMPS.
See Advertisement, page 33, last week.
PATENT WATER-TUBE BOILERS,
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 7179

**John H. Wilson & Co., Ltd.**
Birkenhead.
See Illustrated Advertisement
Page 123, Sept. 12.

**Locomotive Shunting Cranes**
FOR
**Steam and Electric Cranes,**
EXCAVATORS, CRANE-NAVVIES, GRABS, CONCRETE-MIXERS,
SHIPS WINDLASSES, WINCHES, and DECK MACHINERY.
6770
LISTS OF STANDARD SIZES ON APPLICATION.
London Office
15, VICTORIA STREET, S.W. 1.

**Gas and Oil Engine Repairs.**
—E. J. DAVIS & CO., Great Eastern Road, Stratford, E. 15.
Tel.: 736 and 737 Stratford.
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**Petter Oil Engines.**
Manufactured by 3591
PETTERS LIMITED, Engineers, Yeovil.

**Craig & Donald, Ltd., Machine**
TOOL MAKERS, JOHNSTONE, near Glasgow.
For class of Machine Tools see our Illustrated Advertisement every alternate week. 1358

**Electric Lifts**
(UP TO 35 TONS.)
7182
S. H. HEYWOOD & CO., LTD., REDDISH.

**Steam Hammers** (with or without guides). Hand-worked or self-acting TOOLS for SHIPBUILDERS & BOILERMAKERS.
7364
DAVIS & PRIMROSE, LIMITED, LEITH, EDINBURGH.

**Brett's Patent Lifter Co.**
LIMITED.
**Hammers, Presses, Furnaces,**
COVENTRY. 610

**Bever, Dorling & Co., Ltd.,**
BRADFORD.
HIGH-CLASS ENGINES FOR ALL PURPOSES, also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1906

**Cranes.—Electric, Steam,**
HYDRAULIC and HAND,
of all types and sizes.
GEORGE RUSSELL & CO., LTD., Motherwell, near Glasgow. 7364

Telegrams—"Cylinders," Birmingham.
**Weldless-Steel Tubes**
for Water-tube Boilers, Superheaters, Shafting, Hydraulic Work, Boring Rods, &c.
TUBES LIMITED, BIRMINGHAM. 3179

**Yarrow & Co., Ltd.,**
SHIPBUILDERS AND ENGINEERS,
GLASGOW.
SPEEDS UP TO 45 MILES AN HOUR.
PADDLE OR SCREW STEAMERS OF EXCEPTIONAL SHALLOW DRAUGHT.
**Repairs on Pacific Coast**
by YARROWS, LIMITED, Victoria, British Columbia. 6976
SHIPBUILDERS, SHIP REPAIRERS AND ENGINEERS.

**Campbells & Hunter, Ltd.**
SPECIALISTS IN
**Drillers & Boring Machinery**
for Engine Works and Boiler Shops.
DOLPHIN FOUNDRY, LEEDS. 4547

**Yachts, Launches or Barges**
Built complete with Steam, Oil or Petrol Motors; or Machinery supplied. Od 3561
VOSPER & CO., LTD., BROAD STREET, PORTSMOUTH.

**Cochran** MULTITUBULAR AND CROSS-TUBE TYPES.
**Boilers.**
See page 17, Sept. 12. 7303

**Electric Cranes.**
7182
S. H. HEYWOOD & CO., LTD., REDDISH.

FOR
**Drop Forgings**
write
GARTSHERRIE ENGINEERING & FORGE CO., 50, Wellington Street, Glasgow. 7306

**Tank Locomotives**
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 7260

AUTOMATIC ANALYSIS OF FLUE GASES
**Hays $CO_2$ Recorders,**
Draught Gauges, Gas Analysers, Gas Collectors
*Tested out on the High Seas in Naval Ships.* 7854
L. C. HARVEY,
25, Victoria Street, Westminster, London, S.W. 1.
*Telegrams*— *Telephone*—
Fuselecon, 'Phone, London. 4280 Victoria.

**Excavators.**
FROM 50 TO 800 YARDS PER HOUR.
**D. Whitaker,**
6363
1, UNION STREET, LEICESTER.

AERIAL ROPEWAYS, CABLEWAYS, CRANES.
**Steel Castings.**
7319
See displayed advertisement every alternate week.
JOHN M. HENDERSON & CO., ABERDEEN.

**"Spencer-Hopwood" Patent**
Sole Makers:
**Boilers.**
W. H. SPENCER & CO., HITCHIN, HERTS.
*See page* 15, Sept. 12. 7454

**Synonyms:—**
**"Aptol" Oils**
AND 7184
**Economy.**
**Henry Wells Oil Co.,**
11, Haymarket, LONDON, S.W. 1.

Iron and Steel
**Tubes and Fittings.**
6920
**The Scottish Tube Co., Ltd.,**
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement page 105.

**Royles Limited,**
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS, } Row's Patents.
CONDENSERS, AIR HEATERS,
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

**Tubes and Fittings,**
IRON AND STEEL.
**Stewarts and Lloyd's, Ltd.,**
41, OSWALD ST., GLASGOW.
BROAD STREET CHAMBERS, BIRMINGHAM; and LONDON OFFICE—
WINCHESTER HOUSE, OLD BROAD STREET, E.C.
LONDON WAREHOUSE—167, UPR. THAMES ST., E.C.
LIVERPOOL WAREHOUSE—63, PARADISE ST.
MANCHESTER WAREHOUSE—34, DEANSGATE.
CARDIFF WAREHOUSE—132, BUTE ST.
BIRMINGHAM WAREHOUSES—NILE STREET, SHEEPSCOTE STREET, and 10, COLESHILL STREET.
See Advertisement page 39. 7266

**Die Finished Castings**
ensure rapid production and reduce prime cost by eliminating machining operations. Write for illustrations to AERATORS LTD., Edmonton, London, N. 18.

**"Petrolex" Fire Extincteur**
puts out flaming motor spirits, burning oil, electric arcs and every kind of fire.—BRITISH FIRE APPLIANCES Co., Ltd., 109, Victoria St., London, S.W. 1.

**R. Heber, Radford, Son & Squire,**
ENGINEERING, IRON AND STEEL WORKS
**Valuers.**
CONSULTING ENGINEERS, REFEREES, AND ARBITRATORS.
Established over 50 years. 7109
15, ST. JAMES ROW, SHEFFIELD.
Telegrams: "Radford, Sheffield." Telephone: 495.

**Locomotive Traversers**
(ELECTRIC).
7182
S. H. HEYWOOD & CO., LTD., REDDISH.

GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED.
**Duckham's Patent Suspended**
WEIGHING MACHINES.—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c.
See Illus. Advt. last week, page 18. 7046

Patent
**See's Ash Ejector.**
Hydro-Pneumatic
Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4826

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— FOR —
EXHAUST STEAM TURBINES COMPRESSED AIR, &c.
STEAM DRYERS,
METALLIC PACKINGS.
**Princeps & Co.,** 6686
SHEFFIELD.

**Gauges**
FROM
**Stock.**
THE
**Newall Engineering Co.**
(Proprietors, Peter Hooker, Ltd.),
LONDON, E. 17. 7894

**Rubber** MANUFACTURERS
**Belting**
GUTTA PERCHA & RUBBER, LIMITED
Toronto Canada. 7535

CHANTIERS & ATELIERS
**Augustin-Normand**
67, rue de Perrey—LE HAVRE
(France). 3690
Destroyers, Torpedo Boats, Yachts and Fast Boats, Submarine and Submersible Boats.
NORMAND'S Patent Water-tube Boilers, Coal or Oil Heating. Diesel Oil Engines.

**Yarrow Patent**
**Water-Tube Boilers.** 6094
Messrs. YARROW & CO., UNDERTAKE the PRESSING and MACHINING of the various parts of Yarrow Boilers, such as the Steam Drums, Water Pockets, and Superheaters for British and Foreign Firms not having the necessary facilities.
YARROW & CO., LTD., SCOTSTOUN, GLASGOW.

**John Bellamy Limited,**
MILLWALL, LONDON, E.
GENERAL CONSTRUCTIONAL ENGINEERS, 1216
**Boilers, Tanks & Mooring Buoys**
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.
RAILWAY AND TRAMWAY ROLLING STOCK.
**Hurst, Nelson & Co., Ltd.**
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3253

**Head, Wrightson & Co.,**
LIMITED.
See Advertisement page 54, Sept. 12. 2409

ON ADMIRALTY LIST.
**John Kirkaldy, Ltd.,**
London Office: 101, LEADENHALL ST., E.C. 3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice Making Machinery.
Feed Water Heaters.
Feed Water Filters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers.
&c., &c. 7726

**Steel Castings.**
THOMAS SUMMERSON & SONS, LTD.,
DARLINGTON. 7502

**Electric Transporters.**
S. H. HEYWOOD & CO., LTD., 7182
REDDISH.

**P. & W. MacLellan, Limited,**
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c.
Chief Offices: 129, Trongate, GLASGOW. Od 3547
Registered Offices: 108A, Cannon St., London, E.C.

**The Glasgow Railway Engineering Company,**
GOVAN, GLASGOW. LTD.
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORKS, also CAST-STEEL AXLE BOXES. 7312

**Centrifugals.**
**Pott, Cassels & Williamson,**
MOTHERWELL, SCOTLAND.
1908
See half-page Advertisement page 53, Sept. 5.

**B. & S. Massey, Ltd.,** MANCHESTER.
**Steam Hammers,**
**Power Hammers,**
**Drop Stamps,**
**Band Saws.** 7336
QUICK DELIVERY. LARGE STOCK.

## The Manchester Steam Users ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the Attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. T179

## Northampton Polytechnic INSTITUTE, 280, St. John Street, London, E.C.1.

Evening Technical Courses in all Branches of Mechanical and Electrical Engineering will COMMENCE on MONDAY, SEPTEMBER 22ND, 1919.
Full-time Sessional DAY COURSES in Engineering and in Technical Optics will commence on the 29th September, 1919.

The Laboratories, both Mechanical and Electrical, are well equipped with modern apparatus which, on the Mechanical side, provides for specialisation in Automobile and Aeronautical Engineering, and, on the Electrical side, for Specialisation in Alternate and Continuous Current Work, in Radio-Telegraphy and Telephony, and in Electrical Testing.
A 344
R. MULLINEUX WALMSLEY, B.Sc., Principal.

LONDON COUNTY COUNCIL.

## Day and Evening Classes in ENGINEERING

(CIVIL, ELECTRICAL, MECHANICAL AND MARINE)

are held at the undermentioned institutions maintained by the London County Council:—

HACKNEY INSTITUTE, Dalston Lane, E. 8 (Mechanical and Electrical).

PADDINGTON TECHNICAL INSTITUTE, Saltram Crescent, W. 9 (Mechanical and Electrical).

SCHOOL OF ENGINEERING AND NAVIGATION, High Street, Poplar, E. 14 (All except Civil Engineering).

WESTMINSTER TECHNICAL INSTITUTE, Vincent Square, S.W. 1 (Civil Engineering in the evening).

In most cases persons under 21 qualified for admission to the schools or institutes and bona fide engaged in the Trade are admitted free.

Full prospectuses may be obtained on application to the Secretaries of the respective institutions.

JAMES BIRD, A 158
Clerk of the London County Council.

MANCHESTER MUNICIPAL

## College of Technology (UNIVERSITY OF MANCHESTER).

Principal: J. C. M. GARNETT, C.B.E., M.A. (late Fell. Trinity Coll., Cam.)

The Session 1919-1920 will open on 8th October. Matriculation and Entrance Examinations will be held in July and September.

DEGREE COURSES IN TECHNOLOGY.

The Prospectus gives particulars of the courses leading to the Manchester University degrees (B.Sc. Tech. and M.Sc. Tech.) in the Faculty of Technology, in the following Departments:—
MECHANICAL ENGINEERING (Prof. G. G. Stoney, F.R.S.).
ELECTRICAL ENGINEERING (Prof. Miles Walker, D.Sc.).
SANITARY and Municipal ENGINEERING.
THE CHEMICAL INDUSTRIES (Prof. F. L. Pyman, D.Sc.), including General Chemical Technology, Bleaching, Dyeing and Dye-stuff Manufacture, Printing, Papermaking, Fermentation Industries, Metallurgy, Fuels.
TEXTILE INDUSTRIES (Prof. A. J. Turner, M.A., B.Sc.).
PHOTOGRAPHIC TECHNOLOGY.
ARCHITECTURE.
PRINTING.
MINING.

ADVANCED STUDY AND RESEARCH.

The College possesses extensive laboratories and workshops, equipped with full-sized modern apparatus, including machines specially constructed for demonstration and orig... ch.
PROSPECTUSES ... Courses or of
Part-time ... ation. A 115

...ON.

## ...S.—Faculty of ENGINEERING.

Complete COURSES of STUDY, extending over either three or four years, are arranged in CIVIL, MECHANICAL and ELECTRICAL ENGINEERING for the Engineering Degrees of the University of London and for the Diploma and Certificate of the College.
The four years' course provides, in addition to the academic training, opportunity for practical training in "WORKS."

HEADS OF DEPARTMENTS.

| | |
|---|---|
| Professor D. S. CAPPER, M.A., M.Inst.C.E., M.I.M.E. ... ... ... | Mechanical Engineering. |
| Professor A. H. JAMESON, M.Sc., M.Inst.C.E. ... ... ... ... | Civil Engineering. |
| Professor E. WILSON, M.Inst.C.E., M.I.E.E., Dean ... ... ... | Electrical Engineering. |
| Professor S. A. F. WHITE, M.A. ... | Mathematics. |
| Professor J. W. NICHOLSON, M.A., D.Sc., F.R.S. ... ... ... ... | |
| Professor A. W. CROSSLEY, D.Sc., F.R.S.... ... ... ... ... | Chemistry. |
| Professor A. J. ALLMAND, D.Sc. ... | Physics. |
| Professor O. W. RICHARDSON, D.Sc., F.R.S.... ... ... ... ... | |
| Mr. W. T. GORDON, D.Sc., F.R.S.E. | Geology. |

Considerable additions have been made to the Engineering Department. These include two large drawing offices, lecture rooms for the Mechanical and Civil Engineering Departments and lecture theatre and rooms for research, including Wireless Telegraphy for the Electrical Engineering Department. There are six laboratories well equipped with engineering plant and apparatus for the purpose of teaching and research.
Next TERM BEGINS on WEDNESDAY, 1st OCTOBER.
For full information apply to the SECRETARY, King's College, Strand, W.C.2. A 119

## Battersea Polytechnic, London, S.W. 11.

DAY ENGINEERING COLLEGE.

Full Courses in:—
CIVIL,
MECHANICAL, and
ELECTRICAL ENGINEERING,
Preparing for the B.Sc., Degree Examination of the University of London, and College Diploma.

NEXT SESSION COMMENCES September 23rd.

ENGINEERING DEPARTMENT.

Evening Classes are held in all Engineering Subjects, including,
Advanced Structures and Structural Design,
Strength of Materials,
Theory of Machines,
Hydraulics,
Heat Engines,
Municipal Engineering,
Petrol Engines,
Aeroplane Construction,
Surveying, etc., etc.
These classes are suitable for the B.Sc., Inst.C.E., and other Professional examinations.
Next Session commences September 29th.
For further particulars, apply to the SECRETARY, Battersea Polytechnic, S.W. 11. A 266

LONDON COUNTY COUNCIL.

## L.C.C. Westminster Technical INSTITUTE.

Principal: J. STUART KER, B.Sc., A.M.Inst.C.E.

CIVIL ENGINEERING.

The systematic courses in Structural Engineering, Surveying and Levelling, Engineering Mathematics, etc., will re-open on 22nd September, 1919. The Time-table will be based as far as possible on pre-war conditions.
In addition special Advanced Sessional Courses of Lectures will be delivered on Thursdays and Fridays from 6.30 to 8.45 p.m. as follows:—
THE DESIGN OF STEEL FRAME BUILDINGS (with particular reference to the Requirements of the London Building Acts).
Lecturer: H. S. ANDREWS, B.Sc., M.C.I., commencing on Thursday, 25th September, 1919.
STRUCTURAL DESIGN IN REINFORCED CONCRETE.
Lecturer: H. SPRAGUE, A.M.Inst.C.E., commencing on Friday, 26th September, 1919.
These Courses are intended for Civil Engineers and others well grounded in the theory of structural design, but the general principles of structural design bearing on the special problems involved, will be considered throughout the Course for the benefit of those recently returned to practice after war service.
The Prospectus of the Institute, Application Forms, and Syllabus of the Courses with particulars of fee may be obtained on application at the Institute. A 545

JAMES BIRD,
Clerk of the London County Council.

## Inst. C.E. Exams.—Over 300

successes by Correspondence Coaching. Several prizes. Sec. "O" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7494 Offices of ENGINEERING.

## Correspondence Tuition.—

B.Sc., Inst.C.E., Inst.M.E.; also Single Subjects by Honours B.Sc., A.M.I.C.E., etc. Fees moderate.—Address, 7679, Offices of ENGINEERING.

## Inst. C.E., I. Mech. E., B.Sc.,

and all Engineering Examinations.—Mr. G. P. KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 7682

## A. M.I.C.E. and A.M.I.M.E.

Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 264, Oxford Road, Manchester.

## TENDERS.

LONDON COUNTY COUNCIL.

The London County Council invites

## Tenders for Two "Gunboat"

type Steel BOILERS with furnace fittings, smoke-boxes, uptakes, etc., for one of its Woolwich Ferry Boats.
Persons desiring to tender may obtain specifications and drawings from the CHIEF ENGINEER, County Hall, Spring Gardens, S.W.1., upon payment to the Cashier of £3. This amount will be returnable only if the tenderer shall have made a *bona-fide* tender and shall not have withdrawn the same.
Particulars may be obtained and the drawings etc., inspected at the County Hall before the fee is paid.
No tender received at the County Hall after Four p.m. on Monday, 13th October, 1919, will be considered.

JAMES BIRD,
Clerk of the London County Council. A 415

ROYAL BURGH OF ARBROATH.

ARBROATH HARBOUR.

The Town Council invite

## Tenders for:—

(1) Supplying either on sale or hire, suitable DREDGING PLANT capable of thoroughly clearing the Harbour of mud, and for removing same out to sea, or
(2) Carrying out with Contractor's own plant the necessary DREDGING WORK at the Harbour and removing the mud out to sea.

Particulars of work required may be obtained from CAPTAIN EDWARD, Harbour Master, Arbroath.
Sealed offers to be lodged not later than 22nd September curt. with.

ROBT. FINLAYSON,
Town Clerk.

Town Hall,
Arbroath.
11th September, 1919. A 426

## Tender Required for Making

BORE HOLE about 200 ft. deep for well for works water supply.
Capacity 2,000 gallons per hour.—Quotation by the 20th inst. to WILLIAMS & WILLIAMS LTD., Reliance Works, Chester. A 432

## Pumping Machinery Required

to raise 2,000 gallons per hour from well bore hole 200 ft. deep.
Tender by the 20th inst. to,
WILLIAMS & WILLIAMS, LTD.,
Reliance Works, Chester. A 433

BOROUGH OF WEYMOUTH AND MELCOMBE REGIS.

CONSTRUCTION OF DAM AND EMBANKMENT ROAD AND OTHER WORKS.

The Weymouth and Melcombe Regis Corporation invite

## Tenders for the Construction

OF A DAM AND EMBANKMENT ROAD together with the necessary sluices and Tide Flaps and other works at the site of the present Backwater Bridge.
Full particulars may be obtained from the Engineer, Mr. H. W. FITZ SIMONS (Webster & Fitz Simons), 39, Victoria Street, Westminster, who will supply copies of the Specification and Bill of Quantities on receipt of a cheque for £5 5s., which will be returned in the event of a *bona fide* Tender being handed in.
Sealed Tenders endorsed "Tender for Backwater Dam," to be sent to me not later than Monday, October 6th.
The Corporation do not bind themselves to accept the lowest or any Tender.

FREDK. FERNIHOUGH,
Town Clerk.

Municipal Offices,
Weymouth,
September, 1919. A 411

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD.

## Loaded Ammunition. — For

SALE BY TENDER.
About 60,000 tons of (6 in., 8 in. and 9·2 in.) SHELLS, filled with Amatol and lying at various Depots, are for immediate Sale.
Tenders are Invited from responsible firms who have facilities, or who can develop facilities, for removing the explosive and selling the scrap subject to the Home Office Regulations.
The process of removing the explosive is very simple and no elaborate plant and machinery will be necessary.
All inquiries in regard to this announcement should be addressed to the CONTROLLER, R.D.4.a, *Surplus* Government Property Disposal Board, Room 301, Armament Buildings, Whitehall Place, London, S.W.1.
NOTE:—*Surplus*, price 3d., the Official List of Government Property for Sale. Published twice monthly. On sale everywhere. A 447

G. R.

MINISTRY OF MUNITIONS.
BY DIRECTION OF THE DISPOSAL BOARD.

## For Sale by Public Tender.

PLANT AND MACHINERY.
Two 9 in. Lang LATHES.
ELECTRIC MOTORS, 25 HP., 40 HP., 460 volts.
One No. 60 Heald GRINDER.
One Guest INTERNAL GRINDER.
All lying at A.B.C. MOTORS LTD., Walton-on-Thames.
Also:—
Two No. 52 "Acme" four spindle AUTOMATICS.
Two No. 0 Brown & Sharpe Automatic CAPSTAN.
Lying at Messrs. HENNAN & PROUDE, LTD., Worcester.
Tenders to be lodged by Ten a.m., 26th September, 1919.
Detailed list, together with Tender Form and Permit to view, can be obtained from the CONTROLLER, D.B.I.E., Charing Cross Embankment Buildings, W.C. 2.

NOTE.—For *Surplus*, the detailed list of Surplus Government Property for sale, apply at the nearest Bookstall or to a local Newsagent (to whom a standing order should be given), compiled by the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W.1. Price 3d. A 371

THE GREAT INDIAN PENINSULA RAILWAY COMPANY.

The Directors are prepared to receive

## Tenders for the Supply of the

following STORES, namely:—

| | Specification Fees |
|---|---|
| 1.—Ironwork for Vestibules of Corridor Carriages | 7s. 6d. |
| 2.—Steelwork for Bridges | £1 |
| 3.—Brake Rigging | 10s. 0d. |
| 4.—Crank Axles | 10s. 0d. |
| 5.—Brass and Iron or Steel Screws | 10s. 0d. |
| 6.—Bolts, Nuts, Rivets, etc. | £1 |

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Ironwork for Vestibules of Corridor Carriages," or as the case may be, not later than Eleven o'clock a.m., on Tuesday, the 30th September, 1919.
The Directors do not bind themselves to accept the lowest or any Tender.

R. H. WALPOLE,
Secretary.

Company's Offices,
48, Copthall Avenue,
London, E.C.
17th September, 1919. A 517

## APPOINTMENTS OPEN.

## A Large Firm of Engineers

in the Midlands have an OPENING for a YOUTH of good education as premium pupil, the course to include both works and drawing office.—Address, 4389, Offices of ENGINEERING.

BRADFORD EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

DEPARTMENT OF MECHANICAL AND CIVIL ENGINEERING.

## Applications are Invited for

the following Appointments:—
LECTURER IN MECHANICAL ENGINEERING.—Salary £300, rising to £400 by £15 annually. Engineering degree or equivalent qualification and drawing office or works experience essential.
ASSISTANT LECTURER AND DEMONSTRATOR IN MECHANICAL ENGINEERING.—Salary £150, rising to £350 in accordance with scale. Technical training, with degree of diploma, and drawing office or works experience essential.
ASSISTANT LECTURER IN ENGINEERING DRAWING AND DESIGN.—Commencing salary according to qualifications, but not less than £150, rising to £350 according to scale. Technical training, with degree or diploma, and drawing office or works experience essential.
A war bonus of £78 per annum is at present payable to holders of the above appointments.
Full particulars and form of application may be obtained from the PRINCIPAL of the College.
15th Sept., 1919. BY ORDER.
A 481

MADRAS AND SOUTHERN MAHRATTA RAILWAY.

ASSISTANT ENGINEERS.

The Directors of the above Railway Company are prepared to receive

## Applications by Letter Only

for APPOINTMENTS as ASSISTANT ENGINEERS in the Way and Works Department in India. Preference will be given to Candidates not more than about 30 years of age, single, who must have passed the A.M.Inst.C.E.'s examination, or hold an exempting degree, and thereafter should have had experience on survey and construction work or maintenance of open line.
Terms.—A two years' agreement and first-class free passage to India, and return passage on expiry of the agreement.
Salary.—Rs. 500 per calendar month (or according to qualifications).
Selected candidates will be required to pass a strict medical examination by the Company's Consulting Physician before appointment.
Letters of application marked outside "Assistant Engineer," with copies (not originals) of testimonials, should be addressed to the undersigned, not later than 8th October, 1919.

H. BONHAM-CARTER,
25, Buckingham Palace Road,
London, S.W.1.
A 501

UNIVERSITY OF BIRMINGHAM.

CIVIL ENGINEERING DEPARTMENT.

## Applications are Invited for

the POST of JUNIOR ASSISTANT in the Civil Engineering Department. Commencing stipend £200 per annum.
Applications with testimonials and references should be forwarded to the undersigned not later than Saturday, the 27th September, 1919.
Further particulars may be obtained from

GEO. H. MORLEY,
Secretary.

The University,
Birmingham,
September, 1919. A 286

SUNDERLAND EDUCATION COMMITTEE.

THE TECHNICAL COLLEGE.

ENGINEERING DEPARTMENT.

## Applications are Invited for

the POSITION of ASSISTANT in the Engineering Department, at an initial salary of £200-£250, according to experience and qualifications and then by £10 to £350. Applicants must have had teaching, works and drawing-office experience, and be prepared to take the fourth year evening classes in engineering, with laboratory work; the first year of the senior day course, and to supervise some of the testing work done in the Public Testing Laboratory.
Further particulars and forms of application can be obtained from the Principal of the College.
Applicants should apply by letter, with copies of recent testimonials, to the undersigned, as soon as possible, and before Monday, September 22nd. The appointment will be made immediately after that date, in time for the new session beginning on September 29th.

HERBERT REED,
Education Offices, Chief Education Officer.
18, John Street, Sunderland.
6th September, 1919. A 327

BOROUGH POLYTECHNIC INSTITUTE.
Borough Road, London, S.E.1.

## The Governors will Require

in September next for the Day Technical School and Evening Class Department a LECTURER in the Electrotechnics Department.
Candidates should have had good teaching experience and possess a good University degree or its equivalent, but this latter qualification will not be insisted upon in the case of persons otherwise exceptionally qualified. The commencing salary will be £300 per annum, no war bonus, rising by annual increments to £400.
Particulars of appointment and form of application may be obtained by sending stamped addressed foolscap envelope to the undersigned.
Applications must be received not later than 27th September, 1919.

C. T. MILLIS,
Principal.
A 399

# A COMPLETE THEORY OF THE SCREW PROPELLER WORKING IN AIR.

By M. A. S. RIACH, F.R.Ae.S., Assoc. Inst.N.A.

THE present contribution to the theory of the airscrew has been written with the object of simplifying the writer's previous treatment of the subject, and at the same time of retaining that generality which is the cornerstone of the new theory, the latter taking account both of slip and inflow velocity and the rotation set up in the race column.

In any consistent attempt to deal with the highly complex phenomena presented in the action of a screw propeller, it is necessary at the outset to define the boundaries and consequent necessary limitations of the treatment before attempting to bring mathematical analysis into the problem in order to produce results that shall be capable of a quantitative interpretation. The essence of the whole theory depends upon experimental results obtained from aerofoils in a wind-channel. But in view of the fact that the theory is admittedly of an empiric-theoretical nature, it is quite within the province of the treatment to, as far as possible, construct and, if necessary, modify its underlying basis from observation of airscrews working under conditions which approximate to those assumed to be present in theory. If an airscrew be supposed revolving about its axis at a uniform speed, but having no axial motion through the air relative to the undisturbed portions of the fluid at a great distance from the screw, the type of flow generated is something of the form given in Fig. 1.

There is a very well-defined region at *a a*, which appears to form the edge or boundary of the race. Inside *a a* and up to each edge the air is flowing at a relatively great velocity. Outside this boundary surface the velocity is hardly appreciable, and is in the opposite direction. Immediately in front of the screw disc the velocity of the air is large compared to that at *b*, and is in the same general direction as the race. Its magnitude is, for a static test, approximately *one-half* of the velocity of the race.

There is also a fairly well-marked motion of *rotation* in the race, and this also probably exists to some extent in front of the screw disc.

Bearing, then, these few simple facts in mind, it is required to build up a theory which shall to a sufficiently high degree of accuracy be capable of giving a quantitative prediction of the phenomena associated with the action of a screw propeller working in air.

The fact that the race appears to be confined to a particular region behind the screw disc suggests at once an elementary hypothesis, to account for the motion of a purely tentative character to stand or fall by the test of experiment.

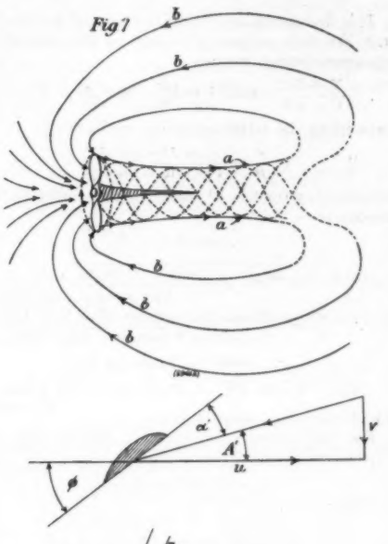
The diameter of the circle *a a* in the above figure has a minimum value of about 0·8 times the diameter of the screw, and an inner core where there is little perceptible motion of the air, depending upon the type and size of boss employed. In front of the screw disc no such well-defined region exists. As already mentioned, however, there is probably some *rotation* of air going on *in front of* the screw disc.

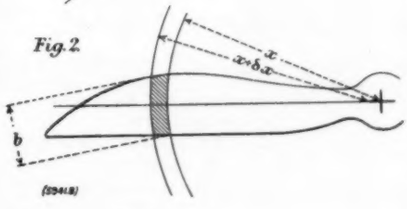
## GENERAL THEORY.

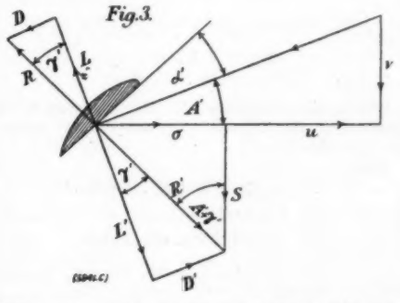
Consider a motion that is bounded by such a well-defined "tube" as actually appears from observation to be the case. The area of a section of this tube multiplied by the velocity of flow through it will then be a measure of the quantity (cubic volume) of air passing during any given period of time. If the motion on both sides of the actuator disc is to be in any way continuous, this quantity must be constant both in front and behind the screw. This, naturally, brings us to our first hypothesis. If we can measure the quantity of fluid passing per second at any point behind the screw by means of the assumption that the fluid behaves more or less as in flowing through a tube of given cross-sectional area, then we may *for convenience* assume also that the fluid *in front of* the screw is also defined by an imaginary tube, although, in reality, the actual motion may be quite different. In other words, if the flow through the screw be continuous, the volume of air passing any section of the wake per second must be the same as the quantity of air *entering* the screw per second.

We shall consider then what happens to an element of blade of an airscrew having a motion of translation and rotation through the air. (Fig. 2.)

The relative velocity of the air and the screw element axially is $v$, and transversely $u$. The angle at which the relative wind strikes the blade element is $A^1$ to the plane of rotation. The angle of section of the blade to the plane of rotation measured from the chord line being $\phi$, we have the angle of incidence or "angle of attack" of the blade section given by $a^1 = \phi - A^1$. On the analogy of an aerofoil




lifting surface, this relative velocity between the blade element and the air produces a reaction proportional to $\left(\frac{v^2}{\sin^2 A^1}\right)$ for a given value of $a^1$. Fig. 3 denotes the force diagram.

Calling R the resultant force reaction on the blade element, L the lift component perpendicular to the relative wind, and D the drag or resistance component parallel to the relative wind, the resultant velocity impressed on the air will be in line with R, but opposite in direction. This is denoted by $R^1$, the other two components being similarly denoted by $L^1$ and $D^1$. It is seen at once that there must be a *motion of rotation* in the race. The two components of $R^1$ will then measure the *slip* axially and transversely.

Denote the ratio $\frac{D}{L}$ by $\tan \gamma^1$, so that $\gamma^1$ is the drag or "friction" angle of the blade section. Cot $\gamma^1$ will then be the lift/drag ratio of the section considered as an aerofoil. Denote the axial and transverse components of $R^1$ by S and $\sigma$ respectively, then it is easily seen from the figure that $\frac{\sigma}{S} = \tan (A^1 + \gamma^1)$. Also, from the figure; $\frac{v}{u} = \tan A^1$. Now $v$ is composed partly of the velocity of the screw axially through the undisturbed air and the slip imparted to the air in the neighbourhood of the actuator.

If V be the axial velocity of advance relatively to the undisturbed portions of the fluid, and S the total axial slip imparted at any radius, then (V + S) will be the total axial wake velocity at that radius relatively to the screw. Some of this slip is present in advance of the screw, and if we assume that the whole phenomena is confined to the imaginary "tube" already defined, it is a simple matter to show that the relative axial velocity at the element is a mean between the initial and final axial velocities, *i.e.*, $v = V + \frac{S}{2}$.

In the same way, if C be the circumferential velocity of the blade element at any radius due to its rotation, and $\sigma$ be the total *transverse* slip imparted at this radius, the total transverse wake velocity between the blade element and the air will be $(c - \sigma)$. Part of this transverse slip is present in advance of the actuator, and employing the same reasoning as before, we find that the relative transverse velocity at the element is again a mean between $c$ and $c - \sigma$, *i.e.*, $u = c - \sigma/2$.

We thus have two equations connecting $\sigma$ and S.

$$(1)\ \frac{V + S/2}{c - \sigma/2} = \tan A^1;\ (2)\ \frac{\sigma}{S} = \tan (A^1 + \gamma^1)$$

The motion of air over the screw element is taken to be purely two-dimensional in character. The boss probably forms an exception to this rule. The end or tip conditions are at present unknown experimentally, but it appears that the assumption of a two-dimensional form of flow right up to the blade tip is not at the worst more than a bad approximation. There is known to be a loss of pressure immediately in front of the screw disc, and this will tend to cause the air to flow inwards towards the centre of the screw and not outwards away from it. This supports the two-dimensional hypothesis.

In passing, we may make the two following observations. From Fig. 3, it is seen that the angle at which the air *leaves* the blade is $A^1 + a^1 + 90° - A^1 - \gamma^1 = 90° + (a^1 - \gamma^1)$. Now, for most values of $a^1$, $(a^1 - \gamma^1)$ is very small compared to 90. Hence, we may at once conclude that the angle at which the air leaves the blade is approximately a right angle. This fact has been ascertained recently quite independently from experiment.*

Eliminating $\sigma$ from equations (1) and (2), we find the value of S is given, viz. :—

$$S = \frac{2 . C [\tan A^1 - \tan A]}{1 + \tan A^1 . \tan (A^1 + \gamma^1)}$$

where $\tan A = \frac{V}{C}$.

Let V = 0, then :—

$$S = \frac{2 . C . \tan A^1}{1 + \tan A^1 . \tan (A^1 + \gamma^1)}$$

So that if $A^1$ is constant, $a^1$ is constant $(A^1 = \phi - a^1)$ for any radius, and hence $\gamma^1$ is constant because $\tan \gamma^1$ is a function of $a^1$ only for any given form of blade section.† That is if $A^1$ is constant S is simply proportional to C, that is proportional to the revolutions per minute of the screw. It will be shown later that $A^1$ is constant when a given screw works statically, as in a wind channel fan. We conclude, therefore that in the case of a fan used in a wind-channel, the fan wind speed in the channel is simply proportional to the revolutions per minute of the motor. This is an experimental fact.‡ Here we have, then, the theory in complete agreement with experiment.

It has been shown how to eliminate $\sigma$ from the equations already deduced, and to obtain S the total slip imparted at any radius in terms of $A^1$, A, C, and $\gamma^1$. But this is not sufficient. We require to eliminate S altogether, or, rather, to obtain

* Morgan Brookes' "Aviation." New York, June 1st, 1918.

† Except for slight V.L. variations.

‡ Morgan Brookes' "Aviation." New York, June 1st, 1918.

another equation connecting the aerodynamical coefficient of *lift* ($Cy^1$) with $A^1$ the angle of the relative wind to the plane of rotation. This is accomplished by equating the sum of the thrusts on the blade elements at any radius, measured aerodynamically as aerofoils, with the momentum change through the annulus defined by the same radius. This has already been done, and the results published.* The generalised formula obtained in this way is :—

$$C\,y^1 = (2\,.\,\mu + c\,x^1)\tan(A^1 - A).$$

Owing, however to the impossibility of determining the form of $\mu$ from lack of experimental evidence, it is usual, and simpler, to compute the volume of air engaged per second at any annulus from the assumption that *all* the air available is usefully engaged in producing thrust, &c. This has been referred to in certain of the writers' earlier papers under the title of the "gap hypothesis." The final formula obtained in this way is given by :—

$$N\,.\,\delta\,.\,Cy^1 = 4\,.\,\pi\,.\,x\,.\sin A^1\,[\tan A^1 - \tan A]\,.\cos^2 A^1$$

where

$x$ = any radius from centre of rotation of screw.
$b$ = chord blade width of section at this radius.
$N$ = number of blades.

It will be seen that this expression is simply a variation of the generalised equation for $Cy^1$ given above, the unknown quantity $\mu$ having been replaced by certain known functions on the hypothesis mentioned above.

We come now to the main purpose of the present work, viz., to simplify the writer's previous treatment, in order to enable airscrew designers to employ the method in the drawing office with the least possible trouble. For this purpose the value of the slip velocity is made constant over the whole screw disc. This, be it noted, is not to be regarded in any way as an approximation. It is a perfectly legitimate process of design. It is now, more or less, generally accepted that for maximum screw efficiency a constant slip velocity should be maintained over the working portions of the propeller blade. This was first pointed out by F. W. Lanchester. In any case, this procedure, whether rigorously true or not in the case of actual airscrews, is probably sufficiently so for our present purpose. Two benefits immediately follow from this restriction :—(1) The airscrew so designed will be as near a maximum efficiency as it is at present possible, either to estimate or obtain, and (2) the mathematical portions of the work become enormously simplified at once. This latter is probably of even the more importance, because once a clear and easy method of *accurate* design has been evolved, progress can go ahead far more quickly than before, when each step requires days of intricate and arduous calculation, and where any slip may upset the whole apple-cart.

### General Analysis.

Let $N\,.\,\delta\,M$ denote the mass of air passing per second through any annulus. Then the torque resistance presented to an element of blade is :—

$$\delta X = \delta M\,.\,\sigma$$

$$\therefore\quad N\,.\,\delta X = N\,.\,\delta M\,.\,\sigma$$

And if C denote the circumferential velocity of the blade element about the screw axis, the work done per second by the motor in driving each element of blade through the air will be :—

$$\delta X\,.\,C.$$

Hence, if $\delta H$ be the B.H.P. (brake horse power) available for turning the sum of the elements at any radius of N separate blades, we must have :—

$$550\,.\,\delta H = N\,.\,\delta X\,.\,C = N\,.\,\delta M\,.\,\sigma\,.\,C$$

and

$$\therefore\quad 550\,.\,H = N\,.\int\sigma\,.\,C\,.\,dM \text{ in lb. ft. sec. units.}$$

This constitutes the fundamental equation for our purpose. It is a simple matter to show that, on the "gap" hypothesis, the total mass per second for any annulus denoted by $N\cdot\delta M$ is given by :—

$$N\,.\,\delta M = \frac{\rho\,.\,(V + S/2)\,.\,(C - \sigma/2)\,.\,\delta C}{2\,.\,\pi\,.\,n^2}$$

where $n$ = revolutions per second of screw in plane of rotation,

and $C = 2\,.\,\pi\,.\,n\,.\,x$,

$x$ = radius distance of blade element from centre of screw.

* The Aeronautical Journal, August, 1918. "The Dynamics of Fluid Propulsion."

substituting for $N\,.\,\delta M$, we obtain :—

$$550\,.\,H = \frac{\rho\,.\,(V + S/2)}{2\,.\,\pi\,.\,n^2}\,.\int\sigma\,.\,C\,.\,(C - \sigma/2)\,.\,dC$$

since S is to be made constant over the blade length.

It remains, therefore, to find the form of the function $\sigma$.

This gives us :—

$$\frac{550\,.\,H\,.\,2\,.\,\pi\,.\,n^2}{\rho\,.\,(V + S/2)} = \int\sigma\,.\,C\,.\,(C - \sigma/2)\,.\,dC$$

We concentrate, therefore, our attention upon the evaluation of the integral.

$$\int\sigma\,.\,C\,.\,(C - \sigma/2)\,.\,dC$$

It is first necessary to find the form of the function $\sigma$. For this purpose we return to the original two equations found, viz. :—

$$\frac{V + S/2}{C - \sigma/2} = \tan A^1, \text{ and } \frac{\sigma}{S} = \tan(A^1 + \gamma^1)$$

expanding the latter equation, we have :—

$$\frac{\sigma}{S} = \frac{\tan A^1 + \tan\gamma^1}{1 - \tan A^1\,.\,\tan\gamma^1}$$

substituting for $\tan A^1$ from the first equation, this becomes :—

$$\frac{\sigma}{S} = \frac{\tan\gamma^1 + \dfrac{V + S/2}{C - \sigma/2}}{1 - \dfrac{\tan\gamma^1\,(V + S/2)}{C - \sigma/2}}$$

$$\therefore\quad \frac{\sigma}{S} = \frac{C\,.\tan\gamma^1 - \sigma/2\,.\tan\gamma^1 + V + S/2}{C - \sigma/2 - V\,.\tan\gamma^1 - S/2\,.\tan\gamma^1}$$

$$\therefore\quad \sigma = C - V\,.\tan\gamma^1 \pm \sqrt{(C - V\,.\tan\gamma^1)^2 - 2\,.\,S\,.\,(C\,.\tan\gamma^1 + V + S/2)}$$

which gives the equation for $\sigma$.

For convenience in writing, denote the root expression by $\lambda$. Then :—

$$\sigma = C - V\,.\tan\gamma^1 \pm \lambda$$

so that—

$$\sigma = C - V\,.\tan\gamma^1 \pm \lambda$$

$$\therefore C - \sigma/2 = C - \frac{C - V\,.\tan\gamma^1 \pm \lambda}{2}$$

$$\therefore C - \sigma/2 = \frac{C + V\,.\tan\gamma^1 \mp \lambda}{2}$$

$$\therefore \sigma\,.\,(C - \sigma/2) = \tfrac{1}{2}\,[C - V\,.\tan\gamma^1 \pm \lambda]\,.\,[C + V\,.\tan\gamma^1 \mp \lambda]$$

$$= \tfrac{1}{2}\,.\,[C - (V\,.\tan\gamma^1 \mp \lambda)]\,.\,[C + (V\,.\tan\gamma^1 \mp \lambda)]$$

$$= \tfrac{1}{2}\,.\,[C^2 - (V\,.\tan\gamma^1 \mp \lambda)^2]$$

$$\therefore \sigma\,.\,(C - \sigma/2) = \tfrac{1}{2}\,.\,[C^2 - V^2\,.\tan^2\gamma^1 - \lambda^2 \pm 2\,.\,V\,.\tan\gamma^1\,.\,\lambda]$$

$$= \left(-V^2\,.\tan^2\gamma^1 + S\,.\,V + \frac{S^2}{2}\right) + C\,.\tan\gamma^1\,.\,(V + S) \pm V\,.\tan\gamma^1\,.\,\lambda + B_2\,.\,C \pm B_3\,.\,\lambda = B_1$$

Where the constants $B_1$, $B_2$, $B_3$, denote the portions of the expression which do not contain the variable C.

Thus :—

$$\sigma\,.\,(C - \sigma/2) = B_1 + B_2\,.\,C \pm B_3\,.\,\lambda$$

$$\therefore \int\sigma\,.\,C\,(C - \sigma/2)\,.\,dC =$$

$$= \int C\,.\,dC\,.\,[B_1 + B_2\,.\,C \pm B_3\,\lambda]$$

$$= B_1\,.\,\frac{C^2}{2} + B_2\,.\,\frac{C^3}{3} \pm B_3\,.\int C\,.\,dC\,.\,\lambda$$

taken between the proper limits for C.

Since :—

$$C = 2\,.\,\pi\,.\,n\,.\,x,$$

where $x$ is any radius and $n$ is constant, the limits of C will be $2\,.\,\pi\,.\,n.\,D/2$ and zero when $x = D/2$ and zero respectively are the limits for the radius. D being the diameter of the screw. If we allow for the boss conditions, the limits of $x$ will be D/2 and $\theta\,.\,D/2$ respectively. Then the upper limit for C becomes $\pi\,.\,n\,.\,D$ as before, and the lower limit $\pi\,.\,n\,.\,\theta\,.\,D$.—

Putting in these limits, we obtain :—

$$\text{Integral} = \frac{B_1}{2}\left[\pi^2\,.\,n^2\,.\,D^2 - \pi^2\,.\,n^2\,.\,D^2\,.\,\theta^2\right] + \frac{B_2}{3}\,.\left[\pi^3\,.\,n^3\,.\,D^3 - \pi^3\,.\,n^3\,.\,D^3\,.\,\theta^3\right] \pm B_3\,.\int_{\theta\,.\,\pi\,.\,n\,.\,D}^{\pi\,.\,n\,.\,D}\lambda\,.\,C\,.\,dC$$

$$\therefore \text{Integral} =$$

$$= \frac{B_1}{2}\,.\,\pi^2\,.\,n^2\,.\,D^2\,.\left[1 - \theta^2\right] + \frac{B_2}{3}\,\pi^3\,.\,n^3\,.\,D^3\,.\left[1 - \theta^3\right] \pm B_3\,.\int_{\theta\,.\,\pi\,.\,n\,.\,D}^{\pi\,.\,n\,.\,D}\lambda\,.\,C\,.\,dC$$

We concentrate our attention, therefore, upon the evaluation of the integral :—

$$\int_{\theta\,.\,\pi\,.\,n\,.\,D}^{\pi\,.\,n\,.\,D}\lambda\,.\,C\,.\,dC$$

putting in the value of $\lambda$, given by :—

$$\lambda = \sqrt{(C - V\,.\tan\gamma^1)^2 - 2\,.\,S\,.\,(V + S/2 + C\tan\gamma^1)}$$

$$= \sqrt{C^2 - 2\,.\,C\,.\tan\gamma^1\,(V + S) + V^2\,.\tan^2\gamma^1 - 2\,.\,S\,.\,V - S^2}$$

$$\therefore \lambda = \sqrt{C^2 - B_4\,.\,C + B_5}$$

where $B_4$, $B_5$, denote the constants in the above expression.

We get, therefore, the final integral =

$$= \int_{\theta\,.\,\pi\,.\,n\,.\,D}^{\pi\,.\,n\,.\,D} C\,.\,dC\,.\,\sqrt{C^2 - B_4\,.\,C + B_5}$$

This presents no difficulties, the solution being :—

$$= \frac{1}{3}\cdot\left(C^2 - B_4\,.\,C + B_5\right)^{3/2} + \frac{B_4}{4}\cdot\left(C - \frac{B_4}{2}\right)\cdot\sqrt{C^2 - B_4\,.\,C + B_5} + \frac{B_4}{4}\cdot\left(B_5 - \frac{B_4^2}{4}\right)\cdot\log_e\left[C - \frac{B_4}{2} + \sqrt{C^2 - B_4\,.\,C + B_5}\right]$$

taken between the limits $\pi\,.\,n\,.\,D$ and $\theta\,.\,\pi\,.\,n\,.\,D$.

Putting in these limits, we obtain :—

Integral =

$$\frac{1}{3}\cdot\left(\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\pi\,.\,n\,.\,D + B_5\right)^{3/2} + \frac{B_4}{4}\cdot\left(\pi\,.\,n\,D - \frac{B_4}{2}\right)\cdot\sqrt{\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\pi\,.\,n\,.\,D + B_5} + \frac{B_4}{4}\cdot\left(B_5 - \frac{B_4^2}{4}\right)\cdot\log_e\left[\pi\,.\,n\,.\,D - \frac{B_4}{2} + \sqrt{\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\pi\,.\,n\,.\,D + B_5}\right]$$

$$- \frac{1}{3}\cdot\left(\theta^2\,.\,\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\theta\,.\,\pi\,.\,n\,.\,D + B_5\right)^{3/2} - \frac{B_4}{4}\cdot\left(\theta\,.\,\pi\,.\,n\,.\,D - \frac{B_4}{2}\right)\cdot\sqrt{\theta^2\,.\,\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\theta\,.\,\pi\,.\,n\,.\,D + B_5} - \frac{B}{4}\cdot\left(B_5 - \frac{B_4^2}{4}\right)\cdot\log_e\left[\theta\,.\,\pi\,.\,n\,.\,D - \frac{B_4}{2} + \sqrt{\theta^2\,.\,\pi^2\,.\,n^2\,.\,D - B_4\,.\,\theta\,.\,\pi\,.\,n\,.\,D + B_5}\right]$$

This expression looks sufficiently cumbersome to warrant a certain amount of pruning. If $\theta > 0$, we calculate for the screw except the boss and near the boss. This boss portion will, however, require a certain amount of power to turn it, and this will have to be computed *separately*, a proceeding that can only be approximate. Moreover, such power required is *small* compared to the other portions of the screw. Hence, it is simpler and within the order of approximation to make $\theta = 0$, and thus allow for the power required to turn the boss portion in the main analysis. The error in doing so will be a small one applied to an already small quantity—in other words a second order error. Hence, applying this restriction, with $\theta = 0$, we get :—

Integral =

$$\frac{1}{3}\cdot\left[\left(\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\pi\,.\,n\,.\,D + B_5\right)^{3/2} - B_5^{3/2}\right] + \frac{B_4}{4}\cdot\left[\left(\pi\,.\,n\,.\,D - \frac{B_4}{2}\right)\cdot\sqrt{\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\pi\,.\,n\,.\,D + B_5} + \frac{B_4}{2}\cdot\sqrt{B_5}\right] + \frac{B_4}{4}\cdot\left(B_5 - \frac{B_4^2}{4}\right)\cdot\left[\log_e\left\{\pi\,.\,n\,.\,D - \frac{B_4}{2} + \sqrt{\pi^2\,.\,n^2\,.\,D^2 - B_4\,.\,\pi\,.\,n\,.\,D + B_5}\right\} - \log_e\left\{-\frac{B_4}{2} + \sqrt{B_5}\right\}\right]$$

And even now this expression is considerably too cumbersome to be of any use for our purpose. It may be noted in passing that all this complexity in the analysis has been introduced by reason of allowing for the drag resistance effect measured by $\tan\gamma^1$. If $\tan\gamma^1 = 0$, the whole of the above expression vanishes. But we cannot make this drastic simplification because to do so would be to defeat one of the objects of the present paper. We require to *retain* the $\tan\gamma^1$ effect, without at the same time making the algebra too cumbersome. This suggests retaining $\tan\gamma^1$ in an approximate, though sufficiently approximate, form.

Putting in the values, we find the complete expression is :—

$$= \frac{B_1 \cdot \pi^2 \cdot n^2 \cdot D^2}{2} + \frac{B_2}{3} \cdot \pi^3 \cdot n^3 \cdot D^3 \cdot$$

$$\pm B_3 \left[ \frac{1}{3} \cdot \left\{ \left( \pi^2 \cdot n^2 \cdot D^2 - B_4 \cdot \pi \cdot n \cdot D + B_5 \right)^{3/2} - B_5^{3/2} \right\} \right.$$

$$+ \frac{B_4}{4} \cdot \left\{ \left( \pi \cdot n \cdot D - \frac{B_4}{2} \right) \cdot \sqrt{\pi^2 \cdot n^2 \cdot D^2 - B_4 \cdot \pi \cdot n \cdot D + B_5} \right.$$

$$\left. + \frac{B_4 \cdot \sqrt{B_5}}{2} + \frac{B_4}{4} \cdot \left( B_5 - \frac{B_4^2}{4} \right) \cdot \right.$$

$$\left. \left. \left\{ \log_e \left( \frac{\pi \cdot n \cdot D - \frac{B_4}{2} + \sqrt{\pi^2 \cdot n^2 \cdot D^2 - B_4 \cdot \pi \cdot n \cdot D + B_5}}{\sqrt{B_5} - \frac{B_4}{2}} \right) \right\} \right] \right]$$

and the value of the constants $B_1$, $B_2$, $B_3$, $B_4$, and $B_5$, are :—

$$\begin{cases} B_1 = V \cdot S + \frac{S^2}{2} - V^2 \cdot \tan^2 \gamma^1 \\ B_2 = \tan \gamma^1 \cdot (V + S) \\ B_3 = V \cdot \tan \gamma^1 \\ B_4 = 2 \cdot \tan \gamma^1 \cdot (V + S) = 2 \cdot B_2 \\ B_5 = V^2 \cdot \tan^2 \gamma^1 - 2\,V \cdot S - S^2 \end{cases}$$

Now consider for a moment the special case when $\text{Tan } \gamma^1 = 0$.

Then this expression reduces to :—

$$\left( V \cdot S + \frac{S^2}{2} \right) \cdot \frac{\pi^2 \cdot n^2 \cdot D^2}{2}$$

which is then equal to the other side of the equation already found, *i.e.* :—

$$\frac{550 \cdot H \cdot 2 \cdot \pi \cdot n^2}{\rho \cdot (V + S/2)} = \frac{S \cdot (V + S/2) \cdot \pi^2 \cdot n^2 \cdot D^2}{2}$$

*i.e.* :—

$$\frac{550 \cdot H}{\rho \cdot \frac{\pi}{4} \cdot D^2} = S \cdot (V + S/2)^2$$

and this relation might have been easily deduced from elementary considerations at the outset without employing the analysis already given.

It is a simple matter to find the value of S from the above equation for any given case. The simplicity of the relationship established has been shown to depend upon the approximation $\text{Tan } \gamma^1 = 0$.

We require, however, to obtain a sufficiently simple relationship to find S, *without* introducing the approximation $\text{Tan } \gamma^1 = 0$.

We require some such equation as :—

$$\frac{550 \cdot H}{\rho \cdot \frac{\pi}{4} \cdot D^2} = \phi \cdot S \cdot (V + S/2)^2$$

where $\phi$ is some function of $\gamma^1$ and S, &c. ; that can be easily ascertained for purposes of a closer approximation.

The right-hand side of the equation is :—

$$\frac{S \cdot (V + S/2) \cdot \pi^2 \cdot n^2 \cdot D^2}{2} \cdot$$

hence we want this outside the main bracket.

Now, for a moment, consider only the first two terms containing $B_1$ and $B_2$, viz. :—

$$\frac{B_1 \cdot \pi^2 \cdot n^2 \cdot D^2}{2} + \frac{B_2 \cdot \pi^3 \cdot n^3 \cdot D^3}{3} \cdot$$

and inserting the values of $B_1$ and $B_2$, this becomes :

$$\frac{\pi^2 \cdot n^2 \cdot D^2}{2} \cdot \left[ S \cdot (V + S/2) - V^2 \cdot \tan \gamma^1 \right]$$

$$+ \frac{\pi^3 \cdot n^3 \cdot D^3}{3} \cdot \tan \gamma^1 \cdot (V + S)$$

$$= \frac{\pi^2 \cdot n^2 \cdot D^2 \cdot S \cdot (V + S/2)}{2} \cdot \left[ 1 - \frac{V^2 \cdot \tan^2 \gamma^1}{S \cdot (V + S/2)} \right.$$

$$\left. + \frac{2}{3} \cdot \pi \cdot n \cdot D \cdot \frac{\tan \gamma^1 \cdot (V + S)}{S \cdot (V + S/2)} \right].$$

Consider the part inside the bracket, and take values for V, S, $n$, D, $\tan \gamma^1$ of 160, 20, 20, 8, $\frac{1}{10}$, respectively, being ordinary values occurring in practice.

Then the value of the expression inside the bracket will be :—

$$= 1 - \cdot 0188 + \cdot 8825 = 1 \cdot 8637$$

by which it is obvious that :—

$$\frac{V^2 \cdot \tan^2 \gamma^1}{S \cdot (V + S/2}$$

can be neglected compared to :—

$$\frac{2}{3} \cdot \frac{\pi \cdot n \cdot D \cdot \tan \gamma^1 \cdot (V + S)}{S \cdot (V + S/2)},$$

which is very important, its value approaching unity.

Now, consider the latter half of the complete integral in the same way, using the same values for V, S, &c.

The values of $B_3$, $B_4$, and $B_5$, will be :—

$$B_3 = V \cdot \tan \gamma^1 = 160 \times \tfrac{1}{10} = 8.$$

$$B_4 = 2 \cdot \tan \gamma^1 \cdot (V + S) = 1 \times 18 = 18.$$

$$B_5 = V^2 \cdot \tan^2 \gamma^1 - S \cdot (2\,V + S) = 64 - 20 \cdot (340) = 64 - 6800 = -6736.$$

The expression is then equal to :—

$$= \pm 8 \cdot [39{,}000{,}000],$$

to be divided by :—

$$\frac{\pi^2 \cdot n^2 \cdot D^2 \cdot S \cdot (V + S/2)}{2} = \pm \frac{8 \cdot 39{,}000{,}000 \cdot 2}{250{,}000 \cdot 20 \cdot 170}$$

$= \pm \cdot 733$, and hence this fraction is of great importance. We can show that the *correct* sign to take is the $-$ *ve*, and hence the complete value will be $1 \cdot 8637 - \cdot 733 = 1 \cdot 1307$, in this example.

We thus see that the important terms, in this last part of the integral, are

$$\pm B_3 \cdot \left[ \frac{1}{3} \cdot (\pi^2 \cdot n^2 \cdot D^2 - B_4 \cdot \pi \cdot n \cdot D + B_5)^{3/2} \right.$$

$$\left. + \frac{B_4}{4} \cdot \left\{ \left( \pi \cdot n \cdot D - \frac{B_4}{2} \right) \cdot \sqrt{\pi^2 \cdot n^2 \cdot D^2 - B_4 \cdot \pi \cdot n \cdot D + B_5} \right\} \right]$$

and, further, that the term

$$\frac{1}{3} \cdot \left( \pi^2 \cdot n^2 \cdot D^2 \right)^{3/2}$$

is not greatly different in value from the complete expression given above.

Had this term been taken in place of the more complete one, we should have got :—

$$\pm 8 \cdot \left[ \frac{1}{3} \cdot (500)^3 \right] = - \cdot \frac{1000^3}{3} = 333{,}000{,}000$$

instead of

$$8 \times 39{,}000{,}000 = 312{,}000{,}000$$

Hence, it is reasonable to retain, in place of the complete term, simply the portion :—

$$\pm B_3 \cdot \frac{1}{3} \cdot \pi^3 \cdot n^3 \cdot D^3$$

*i.e.*,

$$\pm \frac{V \cdot \tan \gamma^1 \cdot \pi^3 \cdot n^3 \cdot D^3}{3}$$

and we retain only the $-$*ve* sign in this. This expression has, of course, to be divided by :—

$$\frac{\pi^2 \cdot n^2 \cdot D^2 \cdot S \cdot (V + S/2)}{2}$$

$$= -\frac{2}{3} \cdot \frac{V \cdot \tan \gamma^1}{S \cdot (V + S/2)} \cdot \pi \cdot n \cdot D$$

The complete expression on the right-hand side of our equation is then :—

$$\frac{\pi^2 \cdot n^2 \cdot D^2 \cdot S \cdot (V + S/2)}{2} \cdot \left[ 1 + \frac{2}{3} \cdot \pi \cdot n \cdot D \cdot \frac{\tan \gamma^1 \cdot (V + S)}{S \cdot (V + S/2)} \right.$$

$$\left. - \frac{2}{3} \cdot \pi \cdot n \cdot D \cdot \frac{V \cdot \tan \gamma^1}{S \cdot (V + S/2)} \right]$$

The portion inside the bracket now becoming :—

$$1 + \frac{2}{3} \cdot \frac{\pi \cdot n \cdot D \cdot \tan \gamma^1 \cdot S}{S \cdot (V + S/2)} = 1 + \frac{2}{3} \cdot \frac{\pi \cdot n \, D \cdot \tan \gamma^1}{V + S/2}$$

$$= 1 + \frac{2}{3} \cdot \frac{500}{20 \cdot 170} = 1 + \frac{1000}{60 \cdot 170} = 1{,}098$$

instead of the more correct value found by the longer method, viz. :—$1 \cdot 1307$, a difference of $\cdot 0327$ in $1 \cdot 307$, *i.e.*, a percentage difference of $\frac{0.0327}{1.1307} \times 100 = 2 \cdot 9$ per cent in this case. This is probably a sufficiently close approximation.

We have thus obtained the type of relation sought, without having to make $\tan \gamma^1 = 0$, the approximations introduced being of a much lower order. Moreover, if $\tan \gamma^1$ be made equal to zero, the form of the expression reduces to the original, as it should do in both cases. It is a simple matter, however, to show the *order* of the approximation introduced by putting $\tan \gamma^1 = 0$. In the above example the error caused would be nearly 10 per cent., which error, whilst being more than three times the error introduced by the approximations finally adopted, is of an entirely different character.

We thus obtain finally :—

$$\frac{550 \cdot H \cdot 2 \cdot \pi \cdot n^2}{\rho \cdot (V + S/2)} = \frac{S \cdot (V + S/2) \cdot \pi^2 \cdot n^2 \cdot D^2}{2} \left[ 1 + \frac{2}{3} \cdot \frac{\pi \cdot n \cdot D \cdot \tan \gamma^1}{(V + S/2)} \right]$$

*i.e.*,

$$\frac{550 \cdot H}{\rho \cdot \frac{\pi}{4} \cdot D^2} = S \cdot (V + S/2)^2 \cdot \left[ 1 + \frac{2}{3} \cdot \frac{\pi \cdot n \cdot D \cdot \tan \gamma^1}{(V + S/2)} \right]$$

A previous result by the writer, gave the particular case when $\text{Tan } \gamma^1 = 0$ in the above equation.*

From this formula it is a simple matter to find S for any given values of H, $p$, D, V, $n$, and $\text{Tan } \gamma^1$.

This completes the first portion of this paper. The second portion will deal with the final applications of this method to the design of screw propellers, particularly air-screws, in a more complete and rapid manner than any so far published.†

*(To be continued.)*

* "Aeronautics," August 29, 1917.

† The foregoing approximations and final result may be obtained in a much simpler manner. The above analysis has been given in full to illustrate the standard of approximation introduced by the simplifications finally adopted.

## THE WORKS AND PRODUCTS OF MESSRS. BARR AND STROUD, LIMITED.

(*Continued from page* 266.)

BEFORE proceeding to a description of some of Messrs. Barr and Stroud's products, we wish to say something of their employment of women during the war. Most of the work involved in the construction of range-finders is, of course, of a skilled nature. Even the repetition work which arises to a considerable extent in connection with the smaller instruments is of a type which the unions class as skilled. As a consequence of this the factory was, before the war, staffed entirely with male labour, the simple work falling naturally to the first and second-year apprentices, although, as we have already made clear, no boys were continually employed on repetition work. The labour shortage arising from the war, however, made it evident during the winter of 1915 that female labour would have to be introduced at Anniesland, as elsewhere.

Opposition from trade unions was overcome, in conjunction with Mr. Lynden Macassey's Dilution Committee, by the introduction of "safeguards." The necessity of observing these safeguards, coupled with the fact that the experiment took place during wartime, resulted, however, in the conditions under which the women were employed becoming somewhat artificial. As a consequence the economic value of the experiment with female labour was destroyed, and no adequate experience was gained bearing on the justification of such employment from a business point of view. The experience, however, gave information of value in other directions. The general results showed that women, with suitable training, could prove as efficient as men in some ordinary instrument-making work. They were very contented to do repetition work, and were regular in attendance and assiduous. In this connection it should be said, however, that the women were young and were specially selected from a large number of applicants; while the unskilled men were generally much older, and many were unused to factory life, while not a few were entirely unskilled in the use of hand or machine tools.

Messrs. Barr and Stroud's maximum complement of female workers was 312. It was originally intended that each woman employed should go through a short course of training to accustom her to factory life and to the names of the various tools, &c., which she would be called upon to handle. It was also arranged to give short explanatory lectures in working hours. This programme was, however, found impossible to carry out, owing to Government instructions not to delay the introduction of large numbers of girls. Only a few women consequently had any training, and those for only a few weeks, before being drafted into the factory.

The first stage in the introduction of women workers was the appointment of a Matron, whose duties were to interview and select candidates, and overlook the welfare and interests of the women in every way. She was not responsible for, nor concerned with, their actual productive work, the control of which lay in the hands of the foremen, but in practice was often consulted by the foremen in connection with shop matters affecting the girls. The Matron was made responsible to the board of directors only, in which procedure the firm followed out their admirable method of clearly defining the scope and duties of their various officials. The

appointment was a great success and the system worked admirably.

The actual introduction of women workers began in February, 1916, when 20 were selected to make a start. In accordance with the scheme to give them an initial training, they for the first week attended only from six to nine in the evening, when they received instructions on various operations in the small range-finder adjusting shop and the optical mounting department. On March 6 a training school was opened in the shop, which now forms the engraving department, and a full day was put in. The women worked on inspection, filing operations, scale dividing and engraving, and leather stitching. Machines were also brought into the school so that training could be given on milling, punching and screw machines, and on tool grinding. After two months it was decided to transfer the women to various departments, the first batch being sent to the small range-finder adjusting and the optical mounting shops. It was at this time that the number of women employed increased so rapidly that the training school had to be given up and the girls placed directly in the works on their arrival.

In connection with the training school, it should be said that so convinced was the firm of its value that it was revived in 1918, when conditions had become somewhat easier. In its new form it was used both for women workers and discharged soldiers, and both theoretical and practical training were given. The restarting of the training school proved, however, to pre-date the signing of the Armistice by only a few weeks, and as this was a signal for the gradual elimination of women from the factory, it was not possible to estimate the value of the revived school as far as the women were concerned.

By the end of 1916 the number of women employed had risen to 267, and in addition to the operations previously mentioned, they were working in the store and time offices, while some were acting as painters and others were doing optical work. About 20 young girls were employed on scale engraving and dividing, and on electric coil-winding in the Fire Control Department. These young girls were found to need a good deal of supervision and required a good disciplinarian in charge. They were more successful in a department of their own than when put in the shops with the men. The number of women employed reached its maximum in May, 1917, when there were 312 in all. The number at the signing of the Armistice in November, 1918, was 291. As the number of girls increased they were employed in a greater range of work, and at the time the maximum number were in the factory there were 62 on fitting and inspection, 59 machine hands, 65 optical adjusters and 68 optical workers and inspectors, the remainder were divided among leather workers, store clerks, &c.

Illustrations showing views in some of the shops during the employment of female workers are given in Figs. 22 to 25 annexed. The illustrations are in the main self-explanatory. In connection with machine work it may be said that Messrs. Barr and Stroud's experience was the common one, that women, while quite satisfactory in operating, say, milling machines, did not attain skill enough to be able to set them up. This, however, may quite well be explained by the briefness of their training. Having said this, it is due to the girl shown operating the milling machine in the foreground of Fig. 22, to record that she individually attained a high degree of skill, and was able to set up her machine and run it completely by herself. In connection with Fig. 24, it may be mentioned that the girl shown in the foreground is operating one of the scale engraving machines which we referred to in our last article. The master scale which is to be copied is mounted on the periphery of the large pivoted wooden sector. It is viewed by the operator through a telescope and a prism, the prism bringing the image into a vertical field. The divisions on the master scale are brought into coincidence with a cross wire in the telescope, and the scale which is being divided (which is mounted on the same moving part, with the master scale), is thus produced as an exact copy of the original. It is

## WORKS OF MESSRS. BARR AND STROUD, LTD., GLASGOW.

FIG. 22. WOMEN MACHINE WORKERS.

FIG. 23. WOMEN ENGAGED ON INSPECTION AND GAUGING.

actually marked off by means of a dividing tool carried by a parallel motion, which is operated by hand when the master scale has been adjusted for position for each division.

In the early days of the employment of women they worked a 44-hour week, the hours being from 8.30 a.m. to 12.30 p.m. and 1.30 p.m. to 5.30 p.m., with 8.30 a.m. to 12.30 p.m. on Saturday. Two 10 minutes' rest intervals were allowed during the day, which were spent in the cloak-rooms, where chairs were provided. When the women went into the shops with the men the different hours for starting and stopping proved inconvenient, and for a time the women were paid overtime when they worked the 50-hour week. This was finally changed and the women all worked a 50-hour week without overtime, but with a concession of 10 minutes' grace at starting and stopping work to avoid overcrowding on the tramcars. The health of the women was good throughout, and it is difficult to make comparisons between the different classes of work in this respect. On machine work the health record was as good as on any other operation, but the best workers were women previously accustomed to factories. Some of the girls new to factory life complained of the standing inseparable from machine operating, and asked for a change, even though seats were provided and were made use of whenever possible. In general the women did not stand heat well, and it was sometimes difficult to get a woman worker to remain at work in a department where there were any chemical fumes. Sometimes it was necessary to try two or three before a girl could be found who could put up with the conditions. In many cases the objection to the conditions was due to physical disability and not to whim.

An ambulance room was provided for the girls, and in the early days when there were but few female employees the attendant nurse was employed on scale dividing, as there was little for her to do in connection with her proper work. This arrangement was a great improvement on that we have more than once come across, in which the difficulty of a nurse having little to do was got over by not employing one. Over the whole period of the employment of women workers there were practically no accidents to them. Two girls lost each the tip of a finger, but otherwise the ambulance room

## WORKS OF MESSRS. BARR AND STROUD, LTD., GLASGOW.

FIG. 24. THE SCALE ENGRAVING DEPARTMENT.

FIG. 25. WOMEN EDGING OPTICAL PARTS.

was concerned only with small cuts and bruises and cases of indisposition. Special canteens were provided for the girls, the first being opened in the hall of the Temple Parish Church in March, 1916. A second one was later opened in three shops which were rented in Great Western Road. The women almost all used the canteens, very few going home for meals. Lunches and teas were provided, and the system of ordering meals beforehand which has been used in the men's dining hall since 1906, was employed. A committee of the girls was formed in 1918 to arrange for music during the dinner-hour.

*(To be continued.)*

## RESIDUAL GAS AND TUNGSTEN DEPOSITS IN GLOW LAMPS.

THE filaments of glow lamps disintegrate and volatilise, especially at high temperatures, and tungsten vapours or compounds are deposited on the walls of the bulbs and blacken the glass. Various means are being used to prevent this blackening. On the one hand substances are purposely introduced into the bulb in which they are to be volatilised in order to bind and to remove the residual bulb gas, thus to improve the vacuum and to deprive the black deposit of its dark colour so that it will no longer weaken the light intensity. Or, alternatively, the bulb is filled with an inert gas (nitrogen) at high pressure to prevent the volatilisation of the filament; the vacuum is thus abandoned. The second method has been successful, and lamps of this type have become known under the rather unfortunate name of half-watt lamps. Historically the former method takes precedence, but the combination of the two apparently contradictory aims, improvement of the vacuum and formation of a transparent deposit, is of recent date. Malignani took a German patent in 1894 on the use of phosphorus for removing the residual gas; later alkali metals and other substances were used. In the laboratories of the General Electric Company (Schenectady) and elsewhere chlorine has been tried for the same object in recent years. At the laboratory of Messrs. Philips' Glow Lamps Works in Eindhoven, Netherlands, they have gone back to phosphorus and other materials, notably glass. We mentioned the remarkable work done by Professor Reinders and Dr. L. Hamburger in this laboratory and in Utrecht on films of metals and salts produced in glow lamps in our issue of November 9, 1917, and we have since referred, in our issue of February 14 last, to Hamburger's studies of the light emission from gases. We now propose to notice two recent papers presented by Dr. Hamburger in conjunction with Mrs. Holst, and Messrs. D. Lely and E. Oosterhuis to the Amsterdam Academy (1919, pages 1062 to 1088). The first paper is on the Removal of Residual Gas, and the second on the Influence of Different Substances on the Light Absorption by Tungsten Films.

When the filament or its support is dipped into a solution or suspension of phosphorus in alcohol and then sealed into the bulb, the phosphorus is volatilised; it binds most of the residual gases, left in the bulb after evacuation, and rapidly clears the bulb of gas, forming an invisible deposit on the glass walls; a very small quantity, 0.05 mgs., of phosphorus is sufficient for the purpose. The reactions are probably complex and not clear. Phosphorus itself, vaporised in a vacuum, is very difficult to condense again; the condensation is rapid when an electric discharge is passed through the vapour, *e.g.*, between the platinum wires. This was observed in 1914 by Kohlschütter to whose researches on the nature of the metal films obtained by cathode volatilisation in various gases we have drawn attention. The metallic particles projected by the discharge would themselves absorb gas; but the glow discharge is sufficient to remove carbon monoxide, nitrogen and hydrogen in the presence of phosphorus, and Hamburger found that, in the presence of phosphorus vapour, even without the electric discharge, the gas pressure was rapidly reduced in the burning lamp and the blackening was prevented. Phosphorus or its oxide—there will be oxidation while the filament is being sealed in—also binds water vapour which is known to be destructive to tungsten filaments.

But Hamburger further observed that he could use glass and some other compounds and minerals in the place of phosphorus. He either powders and sprays the glass on the filament, or he slips glass capillaries over the wires or filaments. At first much more glass was used than phosphorus, and in that case little globules of boiling glass were seen to dance about the wires, finally settling on the cooler portions of the latter. But it was afterwards established that very little glass is required for preventing the blackening. The effect of glass might be explained in several ways. There may be fractional distillation of the glass; the slow evolution of some gas from hot glass, which is very disturbing in high-vacuum work, is now being investigated by Shrader and Sherwood. Hamburger considers not only that alkali ($K_2O$ or $Na_2O$) is liberated from the glass at high temperature—a well-known fact, now utilised in cement works for the potash recovery from the vapours and dust—but also that some free alkali metal is formed by the interreaction between the hot tungsten and the silicate, the tungsten passing into $WO_3$. The alkali would absorb the moisture and some gases; the free metal would itself bind gases. We confess that Hamburger's evidence for the formation of free alkali metal does not seem very convincing. He observed metallic globules; re-evaporating them by heating the bulb, he could not recondense the metal as such, and on opening the bulb and admitting air he found only alkali oxide and $WO_3$ on the glass, of course. He also placed a tiny tube of very thin glass, filled with water in a branch from the lamp bulb, broke it there, and finally found considerable quantities of hydrogen in the bulb gas; this hydrogen, he suggests, was evolved by the action of free potassium on the water, but it does not seem to have occurred to him that the water vaporised might have been dissociated by the hot filament. He states, moreover, that when he coated his filament with $Na_2O$ to start with (not with glass, or sodium silicate), the liberation o sodium failed; but he accounts for this by othe reasons. Using further a quartz capillary and various powdered oxides and compounds in the place of glass, he observed that quartz would answer and that some silicon was liberated, which is quite possible. Of the oxides of thorium, zirconium, tita

nium and aluminium, &c., only magnesia and also some aluminates proved suitable, and he concludes that powdered glass (the kind of glass seemed to be immaterial) or phosphorus are the best substances to prevent blackening of the bulbs; oddly enough the two agents, glass powder and phosphorus, used together did not give satisfactory results.

According to Langmuir, chlorine does not attack tungsten at temperatures up to 200 deg. Introduced into a lamp already blackened with tungsten, the chlorine does not affect the black film until the lamp gets hot. Then the film vanishes, the $WCl_6$ formed being nearly colourless. But the chlorine pressure must be above 0·5 mm. of mercury, and the tungsten chloride is unstable. When the filament is at relatively feeble glow, it is corroded by the chlorine vapours; at high incandescence tungsten is re-deposited on the filament, and if the filaments are not perfectly uniform as to thickness and temperature, both the effects are produced simultaneously and the filament s destroyed. When the chlorine gas pressure is too ow, the bulb does not heat up sufficiently to dissociate the $WCl_6$, and the bulb blackens again after a while, as if no chlorine were present. Thus they did not succeed at Eindhoven in avoiding the blackening or destruction of the filament by direct introduction of chlorine into the lamp. For these reasons Skaupy has resorted to the double potassium thallium chloride $K_2TlCl_6$ which slowly evolves chlorine when hot. The almost colourless deposit then formed on the glass consists of thallium chloride and free chlorine, but does not contain potassium chloride, and by these means, they confirmed at Eindhoven, the blackening can be prevented. The chlorides of copper and silver have similar effects.

Some years ago Needham and others observed that cryolite and even common salt would stop the blackening, and it was suggested that these substances acted like the double chloride, slowly giving off chlorine. According to Hamburger and his colleagues salt, when introduced in a small tube, has no effect; the wire itself must be coated with the salt, but even in that case free chlorine is not evolved, though the electrons emitted at high velocities from the hot filament might decompose the salt and discolour it, just as cathode rays do. The experiments prove that the NaCl is evaporated as such and condensed on the glass wall. The following experiments are interesting. Two tungsten lamps were joined by a glass tube so as to form a double lamp. The filament of the lower lamp was coated with a little salt, the upper not; the latter lamp blackened rapidly. Then a little potassium-thallium chloride was introduced into the lower lamp; in that case there was only a slight blackening in both of the lamps, because the chlorine evolved travelled up into the upper bulb, whilst the salt vapour was at once deposited on the walls of the lower lamp. How is this protective action of the salt to be explained? It is suggested that when the particles of tungsten shot off from the filament strike the glass wall, they condense, and when the bombardment continues they coalesce to larger aggregates which are opaque. When there is a salt coating on the glass, however, the tungsten particles penetrate into this coating and are prevented from coalescing. The colour and transparency of small particles depend upon their size—and other features—and it may be that the blackening is delayed and prevented for some time, as long as the tungsten particles remain separate. The problem requires further investigation. But the conclusion is in accord with the previously-mentioned experiments of Reinders and Hamburger on the optical behaviour of their films of metals and salts. Electric conductivity measurements of the films seem to support the argument, and we know from the experiments of Kohlschütter that the state of dispersion of the metal film produced by cathode volatilisation depends upon the nature of the rarified gas contained in the bulb, though there was little probability in his atmospheres of argon, helium, nitrogen, hydrogen of the formation of compounds. We should add that in the Eindhoven experiments other salts were found to diminish the blackening, *e.g.*, sodium phosphate, tungstate and fluoride, further caustic soda and sodium and calcium fluoride. The salt deposit on the walls should be amorphous, not crystalline. The prevention is not perfect, but the life period of lamps was prolonged 2.6 times by the aid of common salt, and 3.3 times by calcium fluoride, reckoning as the life of a lamp the period during which the light intensity does not sink below 80 per cent. of the initial intensity.

## THE BRITISH ASSOCIATION.
## SECTION G.—ENGINEERING.

WE propose now to deal more fully than we were able to do last week, with the discussions which took place in connection with Section G., on Wednesday the 10th inst., and following days. The discussions on all the papers read were, however, but brief, and apparently no great number of engineering visitors was able to attend the Bournemouth meetings.

### TANKS.

The first paper taken on the Wednesday morning was that of Sir Eustace Tennyson d'Eyncourt, of which we complete the reproduction in the present issue. In view of the instalment of the paper which we printed last week and the continuation in this number it is unnecessary to say anything here about its contents. It was read by the author.

The Hon. Sir Charles Parsons opened the discussion. He said that Sir Eustace d'Eyncourt had hardly done himself justice in the paper and had not made it sufficiently clear to what extent the successful evolution of the tanks was his work. Sir Eustace was very largely responsible for their design and it was due to him that they finally took the form they did, with a bow like a ship. In view of the success of the tanks in practice it was important to remember that the designers were faced not only with an entirely new problem, but also with something nearly like active discouragement from military men. He (Sir Charles) had been consulted in connection with the tanks at the critical period when they were approaching success. He had been at the trials at Hatfield and at the time made it his business to talk to many generals and other high-placed military officers about them. The common opinion he found among such people, even after the successful trials, was that they didn't think much of the idea. This sort of thing was hardly encouragement to the designers, and in view of their perseverance and final success it was interesting to see that Ludendorff now gave our tanks credit for the break-up of the German Army in 1918. The evolution of the tank was one of our greatest achievements during the war. It started from nothing and was not a case of carrying on work already done, or copying, as with airships. It was almost impossible to give too much credit in this matter. Sir William Tritton was a genius in the particular constructions with which he was concerned. It gave him (Sir Charles) great pleasure to pay a tribute to him, as also to Major Wilson and Sir A. A. G. Stern.

Mr. J. S. Wilson, who was called on by Professor Petavel, the chairman, said that he was really unfitted to speak on the subject of the tanks. He thought the most extraordinary thing about the matter was that such an entirely new machine could be designed and successfully manufactured in large quantities in so short a time. The tank was far more revolutionary than the torpedo, but it had been brought to a high state of efficiency in an enormously shorter time.

Professor Petavel said that he also would like to join in the expression of admiration of the effort of organisation, skill and energy which had produced the tanks. He thought the achievement showed that when the need was really there we could go ahead in this country as quickly or quicker than anywhere else. He thanked Sir Eustace for his valuable paper and also for coming down to Bournemouth to read it to them.

### MILITARY BRIDGES.

The next paper taken was that by Professor C. E. Inglis entitled "Portable Military Bridges." It was read by the author. This paper, which we propose to reprint later, was concerned with a description of a type of military bridge designed by Professor Inglis and used to a very large extent in the war. The bridge was essentially built up of tubes and socket castings and involved no bolts or other loose small parts. It was capable of being erected in a very short time or in the dark.

Sir J. A. Ewing opened the discussion on the paper. He said that Professor Inglis had dealt with the matter so fully and clearly that there was practically nothing left to ask. The paper towards the end dealt with bridges specially constructed to carry tanks. This linked it with Sir Eustace d'Eyncourt's paper and he thought that one could not have a better example than these two papers together of how we won the war. The President (Professor Petavel) had said the day before that it was easy to disparage our record or to point to defects which tarnished our record, but the fact remained that whereas in 1914 we were inferior to the enemy in every military asset except moral courage, in 1918 victory came as the result of mastery in practically all the thousand factors on which modern war depended. A better illustration of how this had been done could not be had than these two papers. One paper recorded the achievement of many men—a brilliant result of committee work. The other, the paper then under discussion, concerned itself largely with the work of one man, the author. He personally was deeply gratified at Professor Inglis's success, particularly as he was an old pupil of his.

The only other contribution to the discussion was from an officer present who said that the more the bridges were used by the military authorities, the better they were liked. The absence of loose bolts and small parts which could get lost was a very important feature. The method of using part of the bridge structure for rafting purposes was also very valuable, particularly in getting up supplies to the front and getting heavy objects over rivers with no special preparation of the banks.

In view of the short time available for the rest of the sitting the president then announced that the discussion would have to close and the next paper be taken.

### GEARED TURBINES.

Mr. R. J. Walker accordingly then read his paper entitled "Development of Geared Turbines for the Propulsion of Ships." As we propose to print this paper in full in a later issue we need not say much about it here. It formed a resumé of the development of marine geared turbines from the installation of the Vespasian to the latest and largest installations in the Navy. The paper really constituted a brief history of the application of the turbine to marine work and did not confine itself merely to geared examples.

Sir Eustace Tennyson d'Eyncourt was the first speaker in the discussion. He said he would like to testify to the enormous benefits which the Navy had obtained from the introduction of the steam turbine and gearing. Before gearing was used and it was impossible to accurately make the propeller to suit the turbine speed a propulsive coefficient of about 40 per cent. was obtained. Gearing, by making the best propeller speed possible of attainment, had raised this to about 60 per cent. This was a very important improvement. It meant that with 20,000 h.p. one could now do work which without gearing would require 30,000 h.p. Apart from the weight and size of machinery and boilers this also, of course, meant less coal to be carried and improvement of design all round. At one time during the war we were a little shaky in reference to the supply of oil. Destroyers were the great oil eaters, and if we had had no gearing the position would have been much more serious. The largest geared turbine ships in the Navy were the Courageous and Glorious. These had machinery similar to the Champion, but duplicated. He had recommended the arrangement in view of the success of the Champion. It was quite likely that gearing would be adopted in all future ships. Mr. Walker had done much of the work which had led to the success of marine gearing and had proved a very able lieutenant to Sir Charles Parsons. He believed the perfecting of the tools for the manufacture of gearing was largely due to Mr. Walker.

Commander Hefford, of H.M.S. Malaya (which

was lying off Bournemouth at the time of the meetings), who was invited to speak by Professor Petavel, said that he could not say anything of gearing, but on his ship, which had direct-coupled turbines, they were very successful. They were a great help to the *personnel* in manœuvring and control as compared with reciprocating engines. The lack of wear was remarkable, and after three years' service the main bearing showed wear of less than $\frac{1}{2,000}$ in.

This concluded the formal discussion on the paper, but several questions were asked by members of the audience. In particular both Professor Wilkinson and Professor Hudson Beare asked about the consumption of 10·3 lbs. of steam per kilowatt hour which was quoted by Mr. Walker. They wished to know if this included auxiliaries. Another speaker asked how the gears were machined now.

Mr. Walker, in reply, said that the consumption of auxiliaries was not included in the figure of 10·3. The gearing was hobbed, and no alteration had been made in the method described in Sir Charles Parsons' paper read before the Institution of Naval Architects. The wheels were of mild steel and the pinions of 3 per cent. to 4 per cent. nickel steel.

This concluded the meetings for the day and, as stated in our last issue, an excursion was made to Christchurch R.E. Training Camp in the afternoon to see a demonstration of bridge construction of the type dealt with in Professor Inglis's paper.

### Airships.

The meeting on Thursday the 11th inst. opened at 10 a.m., Professor Petavel, the President, being in the chair. The first paper taken was that by Lieut.-Colonel Cave-Brown-Cave, and entitled "Airships." It was read by the author. We reprinted the paper on page 356 of our last issue.

Sir Charles Parsons was called upon by Professor Petavel to open the discussion, but said he was too much of an outsider in the matter to discuss the paper, although he held very strong opinions about the future prospects of the airship.

Sir Eustace d'Eyncourt, who was next called on, said that he was not very competent to speak on the matter, although he had had charge of the design of Admiralty airships until the end of 1916. After that he feared he had fallen somewhat out of date. He thought very remarkable research work had been done in this country by the National Physical Laboratory, and others, on fabrics and other airship details, and that starting a long way behind the enemy we had caught up to him and, he thought, beaten him. In connection with the proportions of airships, in one sense the nearer one got to a sphere the better. He had advocated a larger diameter in proportion to the length from the first. By increasing the diameter one got no more resistance to movement through the air and at the same time increased lift. The Germans, however, had not worked on this line and their airships got longer and longer in proportion to the diameter. On the question of the danger of hydrogen, there was, of course, the military point of view. An airship was a large target and one filled with hydrogen was very vulnerable. Helium was 10 per cent. heavier than hydrogen, but as compensation one got much less loss by diffusion. The author, in his paper, had not referred to rigid airships with frames of wood. Some years ago the Admiralty had produced such a ship of the Schutte-Lantz type, and for strength it was equal to a Duralumin construction. He thought the whole question of airships wanted reventilating from the naval point of view. Heavier than air machines could now do much of the work which was once proposed for airships, owing to the introduction of aeroplane carrying ships. By this means heavier than air machines could be taken right up to the line. A lighter carrying an aeroplane had been towed up to the line at 30 knots and the aeroplane then took off.

Professor F. C. Lea said the paper was a splendid resumé of the work which had been done on airships. There were a few points he would like to mention. One had reference to the framework of built-up ships. He had been connected with a lot of experimental work on this matter in the early days and found that there were many special points that wanted watching. A built-up member, for instance, might fail in several ways. In the first case it might fail directly under test, but if it did not, it might go down owing to secondary or, what he might call, tertiary failure. Secondary failure was failure of an element as the result of secondary stresses. Tertiary failure was the failure of a joint or connection between elements. A great deal of research was still necessary if we were to learn the most perfect way of using material in such structures. He was hopeful also that something might be done by improvements in light alloys. In most of these the breaking load was quite good, but there was room for much improvement in the ratio of the elastic limit to the breaking load.

Dr. W. Rosenhain referred to the table, included in the paper, giving the breaking length of various materials which were used for reinforcement. The breaking load for Duralumin was given in that table as 24 tons per sq. in. We now had light alloys which gave a figure half as much again as this and for which the breaking length (which was really a way of stating the specific tenacity) would be 21,000 metres. The point mentioned by Professor Lea was important. Failure under stress depended on the elastic limit and not on the tensile strength, but on the whole we were gradually improving matters in this direction. Experimental work of this kind was difficult and slow. Practically the only way of working was to make specimens of new alloys and test them.

Sir Charles Parsons, in proposing a vote of thanks to Lieut.-Colonel Cave-Brown-Cave, suggested that he should design a ship, say, 15,000 ft. long, and see how it worked out.

### Progress of Aviation.

The next paper on the agenda was that by Dr. Leonard Bairstow entitled "The Scientific Progress of Aviation during the War." As we intend to print Dr. Bairstow's paper in full in an early issue, we need not deal with its contents here.

Professor G. H. Bryan was the only speaker in the discussion. He stated he would like to say a few words on the early work he had done in connection with aviation. What he had tried to do was to work out things mathematically and find the conditions necessary to make an aeroplane stable. His idea had really only been that the matter would be of value to mathematicians and would form an interesting study. No other mathematician, however, had ever taken the matter up. What had happened was that Dr. Bairstow, who had had a very practical training, got hold of his book and found it to consist of very cut and dried mathematics. He had started experimenting and had tried to use the mathematics of the book. Much trial and error had been expended on experimental work, but if we could have used some of the pure mathematics now running to waste we might have already solved some of our difficult problems. What he (Professor Bryan) wanted to do was to extend the equation we had for small oscillations about a steady motion, to large oscillations about the most unsteady motion possible.

This concluded the discussion on the paper, and after conveying the thanks of the meeting to Dr. Bairstow the president at once called on the author of the following paper. In view of the little time left for the three following papers, they were each taken without discussion, and all we have to do here is to indicate briefly their contents.

### Engine Power and Height.

The first of these three papers was that entitled "The Relation of Engine Power and Height," by Colonel H. T. Tizard. It was read by the author. The paper stated that in the early days of the war, when it was decided to reduce all officially observed performances of aeroplanes to a standard atmosphere, it was assumed that the horse-power of an engine depended on the engine revolutions and the density of the atmosphere, and was independent of atmospheric temperature so long as the density remained constant. If the error involved in this assumption was large, the standard method of reducing performances became unreliable, and the accuracy of comparisons between model and full scale experiments in aerodynamics was considerably affected. The opposing theory that engine power depends only on the pressure, and not on the density, of the atmosphere had recently found considerable support. In the paper the accumulated evidence from actual flight tests, and from experiments on the ground under artificial altitude conditions, was examined, and it was concluded that, although the density theory was not quite true, the standard method of reducing performances was satisfactory when extreme accuracy was not desired. For accurate comparisons of full scale and model experiments special corrections had to be introduced. We shall print Colonel Tizard's paper later.

### Sound from Airscrews.

The next paper was one by Professor G. H. Bryan entitled "Observations on the Sound Emitted by Airscrews." It was read by the author. The paper began by stating that when airscrews were run on the large whirling arm of the Royal Aircraft Establishment the sound emitted showed only faint traces of the low bass note, resembling an organ tone, which was often conspicuous when aeroplanes were flying overhead; on the contrary, the principal sounds of definite pitch heard were roughly of 400, and in lesser degree 200, vibrations per second, the calculated pitch due to the revolution of the blades being about 70, 40, and 30 per second in the several cases. When, however, the screws were mounted in *fixed* bearings on the spinning tower, and the sound observed in the neighbourhood of the plane of rotation, the low bass notes were very conspicuous and agreed closely with the number of beats per second calculated from the revolution of the blades—namely, 50, 55, and 60 for a three-bladed screw and 33, 37, and 40 for a two-bladed screw at 1,000, 1,100, and 1,200 revolutions per second. With the two-bladed screw running at the higher speed the octave (say 80 per second) was also conspicuous. In the case of an airscrew of which the tip velocity exceeded the velocity of sound (say 1,180 ft. per second), an extremely unpleasant crackling sensation was experienced in the neighbourhood of the plane of rotation.

The observations led to the conclusion that when an aeroplane was observed flying sideways the low organ-pipe tones that were observed were due to the direct action of the blades of the screw upon the air, but their intensity decreased as the angular distance of the observer from the plane of rotation increased, thus accounting for the rise and fall of the sound with the rotary oscillations of the aeroplane, as well as for the unfavourable results obtainable in the whirling arm tests. As, however, the pulsations of an eight-cylinder engine agreed in frequency with those of a four-blade screw, tones of nearly the same pitch might also be produced by the engine, and these were often heard when an aeroplane was receding. They differed in tone quality from those due to the screw, and the motion of the machine gave rise to a slight difference in pitch.

In the case in which the tip velocity exceeded the velocity of sound, the disturbances produced in three different positions of the tip might reach the observer at the same instant during a certain portion of each period, and at the beginning and end of this portion the disturbance *theoretically* became infinite, thus accounting for the unpleasant sensation and its limitation to a very narrow zone near the plane of rotation.

A systematic study of the phenomena involved an examination of the theoretical sound effects due to moving surfaces and moving sources, and certain difficulties present themselves which were evidently anticipated by the late Lord Rayleigh in his "Theory of Sound." So far as these difficulties were due to physical considerations Professor Bryan found that they in great measure disappeared when instead of working with the *velocity potential* we noticed that it was on the *condensation* that the sound effects mainly depended. At that stage the mathematical work became rather heavy, and confirmed Messrs. Lynam and Webb's use of Bessel's Functions in that connection. He had, however, made a simple graphical construction for the vibration curve due to a revolving source, with special reference to cases in which the velocity of revolution exceeded the velocity of sound. The fluctuations producing the effect of sound were due partly to the varying distance of the source from the

observer, and partly to the variations in the interval between the time of emission and the time at which the disturbance reached the observer. An important practical application consisted in determining theoretically the law according to which the intensity of the sound should diminish with the distance as well as its dependence on the rate of revolution. So far as could be ascertained at present, the effect of a revolving source was more like a doubled than a variable fixed source, the condensation due to the former varying as the inverse square, and of the latter as the inverse first power, of the distance. On this assumption the sound of the exhaust should be heard further off than that of the airscrew, even when both were of the same pitch.

### Air Brakes.

The final paper taken at the Thursday meeting was one by Captain R. Rolleston West entitled "Air Brakes, Steep Landings and Short Runs." It was read by the author. It was concerned with experiments which had been made towards fitting aeroplanes with some form of air brake to assist in landing on small and more or less enclosed areas. Land brakes could, of course, be used for this work, but were not very satisfactory. Air brakes fitted to the landing chassis were tried as also flaps both on the front and rear of the wings. Dipping flaps on both the leading and trailing edges of the wings had some success, but the final conclusion was that steep descent and a short run on landing would best be obtained by modifying the aeroplane itself and not by fitting brakes of any sort.

On the afternoon of this day—Thursday—the Engineering Section payed a visit to the Gas and Water Company's Works at Bournemouth.

### Directional Wireless.

The first paper taken at the meeting held on the morning of Friday the 12th inst. was one by Captain J. Robinson entitled "Directional Wireless with Special Application to Aircraft." It was read by the author. Captain Robinson began by saying that ordinary methods of navigation were not normally applicable to aircraft. When navigating a ship it was possible to lay off a course and rely on dead reckoning to give her position at any time, a check reading being made from the sun or stars whenever possible. This procedure acted satisfactorily because drift did not come in to any great extent. Matters, however, were very different with aircraft with which drift might amount to 50 miles an hour, and other methods of navigation were necessary. Of such methods those dependent on some application of wireless telegraphy were the best. At the beginning of the war wireless navigation of this kind was worked by means of a coil fixed on a vertical axis and carried by the aeroplane. When such a coil received wireless messages from outside the maximum signal was given when the coil lay in the direction of propagation. When it was at right angles to the direction of propagation no signal, or practically no signal, was obtained. The size of coil which could be carried on an aeroplane was, of course, comparatively small and this method was not capable of giving other than very weak signals. Later the Bellini-Tosi system was adopted in which two coils at right angles were used and a more audible signal was obtained.

There were two methods on which wireless navigation of aircraft could be carried out. In the first the machine sent out a wireless call asking for its position. This was picked up by two or more stations and transmitted to a central station which worked out the position and then transmitted it to the aircraft. The second method was for the aircraft to have its own direction-finding apparatus on board. The first method was largely used by the Germans in connection with their Zeppelin raids over this country. The drawback from their point of view was that we received the messages sent out by the Zeppelins as well as they did and so discovered the position of the ships. The method was obviously limited in its application and much wireless transmission was necessary to give one airship its position. It was believed that the Germans found it impossible to control more than eight to ten airships at one time in this way.

With the directional wireless apparatus fixed on the machine, the most sensitive position was when the minimum strength of signal was received. This applied either to the single coil on the Bellini-Tosi system. When the coils were used on the ground they were swung to find the minimum signal in each direction and then the mean was taken. On an aeroplane there was considerable noise, and it was necessary to get as loud a signal as possible. There were two coils at right angles swinging on a common axis. The method was to use one coil and get somewhere near the maximum signal. The second coil was then introduced and its effect could either be added or subtracted. If the first coil was not correctly in the maximum position the second would not be in the minimum and so a signal would be heard.

To obtain as strong a signal as possible the coils were made as large as possible. They were wound on the main frame of the machine, one parallel to and the other at right angles to the direction of travel. The machine was then swung about when working out directions. This method had proved very useful with machines returning to the base after bombing raids or other work. The method, however, obviously had the objection that one could not set a course and keep it. The machine had to be swung about and the navigating people objected to this. To overcome this swinging out of course, moving coils had been introduced. They were about 4 ft. high by 3 ft. wide. The strength of signals obtained was not in any case very great and disturbance was caused by the magneto. These, however, were short wave disturbances (5 metres to 30 metres) and could be cut out fairly well by damping with a choke coil. The best way, however, was to screen off the whole magneto. There was further difficulty from the main frame of the machine in which there was frequently a good deal of metal. Errors due to this could, however, be eliminated by a good navigator by swinging the aeroplane in the same way that magnetic errors in a ship's compass could be overcome by swinging the ship.

A position worked out by a flying aeroplane from messages received from one station had an average error of 1¾ degrees or 20 miles in 500 miles. With messages received from two or three stations transmitting one after the other one could get within 7 miles in 500 miles. Seven miles error was quite good enough for bombing work in which the machines would be flying high and could usually see considerably further than 7 miles. The question of why we did not get greater accuracy than this had, however, to be considered. It was quite possible to design coils to be accurate within ¼ of a degree. A variation was found, however, even with work on the ground and interrupted or continuous waves seemed to make no difference. The variation seemed to be connected with states of the atmosphere. At the end of his paper Captain Robinson exhibited a map of a flight from London to Paris directed entirely by directional wireless. The day was very foggy and the ground was not seen after leaving England. The map showed that a straight course was flown and the pilot forecasted correctly within two minutes when he would arrive at Paris.

Lieutenant-Colonel Cave-Brown-Cave was the first speaker in the discussion. He said that from the point of view of the airship not only the longest distance over which wireless messages could be transmitted, but also the shortest was of importance. Outside all questions of navigating airships one had the question of landing, and if wireless messages could indicate distances of a few hundred feet with great accuracy they might greatly assist the landing of airships under difficult conditions.

Sir J. A. Ewing said that in the development of navigation by means of wireless telegraphy we were in advance of the Germans. Captain Robinson had referred to the locating of the position of a Zeppelin by working it out from a message from her picked up by two stations. The Germans used this method, as Captain Robinson had said, but we used it before they did and so traced the movement of Zeppelins before the Germans had worked out any similar method of controlling them.

Professor Petavel, in closing the discussion, said that directional wireless would be of great value in civil aviation in facilitating navigation in fog or in the dark. Captain Robinson had not made it clear to what extent he himself was responsible for many of the best methods which had been worked out and applied.

### The Thermionic Valve.

The meeting then passed to the discussion of three papers dealing with the thermionic valve. They were entitled "The Three-Electrode Thermionic Valve as an Alternating Current Generator," "A New Arrangement for Generating Oscillations by means of Thermionic Valves," and "A Trigger Relay Operated by Thermionic Valves." The first paper was by Professor C. L. Fortescue and the second and third by Professor W. H. Eccles. They were read by their authors. Professor Fortescue's paper, which we propose to reprint in full later, dealt with the use of the thermionic valve as a transmitter in connection with naval wireless telegraphy. The action of the valve was also dealt with, and a mechanical analogy was described which might assist in understanding the electrical action.

Professor Eccles was the only speaker on this paper. He said it was of great interest as giving some information dealing with what the Admiralty had been doing in connection with wireless telegraphy during the war. The mechanical analogy suggested by Professor Fortescue was interesting, and no doubt many students were assisted by parallels of that kind, but for himself he confessed he was more inclined to explain the action of the mechanical analogue in terms of the behaviour of the electrical apparatus than *vice versa*.

Professor Eccles then read his papers. The first was concerned with a method of using two valves in parallel for generating oscillations. Various arrangements of connections were shown, and the effect was a combination which oscillated much more freely than single valve circuits. The second paper described a method of coupling up the valves which gave a combination of great sensitiveness and which could be used for operating a relay. The combination was so sensitive that if it were connected to an ordinary telephone receiver a small sound 10 ft. away or more would be sufficient to make it operate, and the relay to close or open, as the case might be.

Professor Howe was the only speaker on Professor Eccles's papers. He said that the thermionic valve was one of the most interesting pieces of electrical apparatus which had been developed during the war. The valve was invented in 1906 or 1907, but lay dormant until 1912. Since then its development had been enormous. Professor Eccles had shown to what extent variations were possible with it. His double-valve arrangement was something like the change from a single-crank engine to a double-crank engine. The device would also obviously improve the wave form.

### Gaseous Ignition by Hot Wires.

The final paper on Friday's sitting was one by Professor W. M. Thornton, entitled "The Ignition of Gases by Hot Wires." It was read by the author. The paper stated that the question dealt with was important where the possibility existed of inflammable gases coming into contact with incandescent wires, in coal mines or submarines, for example. From an examination of the behaviour of wires of platinum, nickel, iron, tungsten, molybdenum, gold and silver heated by electric current in mixtures with air of hydrogen, methane, ethane, pentane, etylene, methyl and ethyl alcohol, ethyl ether, benzene, coal gas and petrol, the following conclusions were reached:—(1) The least igniting current was a linear function of the diameter of the wire. (2) Ignition was for a given size of wire independent of the calorific value of the gas. (3) It was independent of gas pressure down to a limit of about 10 cm. Hg, when it suddenly failed. Above atmospheric pressure it rose slightly. A platinum wire 0·02 cm. diameter ignited hydrogen (30 per cent.) at 5·45 amperes at atmospheric pressure, and at 6 amperes at 100 lb. per square inch. (4) Gaseous combination, which proceeded automatically to explosion, began, in the case of platinum wires, with the wire at about 200 deg. C., well below red heat. (5) With an explosion vessel of 50 c.c. volume it was practically impossible to ignite methane by

hot wires. Platinum wires glowed white-hot and melted, but did not ignite the gas, which, on being tested afterwards with a spark discharge, immediately exploded. (6) Electric and magnetic fields had no direct influence on hot-wire ignition. (7) The temperature of platinum wires glowing brightly by surface combustion was, when measured by its change of electrical resistance, much lower than the apparent optical temperature. (8) Ignition was traced to an action occurring, if not within the surface layer of the metal itself, so close to it that the ordinary gas laws did not come into action. It was inferred that the mechanism of hot-wire ignition was an attack upon oxygen either within the wire or by positive ions of combustible gas ejected from it.

Professor Petavel at the conclusion of the reading of the paper, said that Professor Thornton was in the habit of bringing new and somewhat upsetting pieces of information to meetings of the British Association. There was clearly some connection between the phenomena described and that of surface combustion. In connection with the statement that platinum wires could be melted in a methane mixture without igniting it and yet that the same mixture could be instantly exploded by a spark, surely there was a spark when the platinum wire finally broke. Why did this not ignite the gases?

Professor Thornton, replying to this, said the reason was that the spark produced at melting was a low-voltage one. It was a high-tension spark which produced explosion.

This concluded the meeting. In the afternoon of this day, Friday, the Engineering Section paid a visit to the Royal Naval Cordite Factory at Holton Heath.

### Submarine Mining.

At the meeting on Saturday morning, the 13th inst., the first paper taken was one by Commander A. L. Gwynne, on "Submarine Mining." In the absence of Commander Gwynne, the paper was read by Professor Howe. The paper began by saying that the mine had appeared in 1776, and had since then been used in every great war. Particularly had it played an important part in the American Civil War, the Russo-Japanese War, and the Great War just concluded. Both Fulton and Colt had contributed to the development of the mine in early days. From 1860 onwards the construction of mines had been carried on particularly by Germany and Russia and some of the smaller Powers. In 1902 there was considerable development in deep sea mines, and the extraordinary success of deep sea mines in the Russo-Japanese war led to still further development. In England, however, the general opinion was that mining was not of value to a Power having command of the sea, and that it should be abandoned. After the Russo-Japanese war some naval officers were in favour of developing mines, but general naval opinion was still opposed to them, and in 1906 the use of mines for the protection of ports was definitely abandoned in this country. Other countries, however, did not take the same step.

In 1914 our mining equipment consisted of a small force of minelayers and a few deep-sea mines, but no mines for the protection of ports. Russia and Germany, on the contrary, were both fully prepared in the matter of mines, and all their warships, other than line ships, were fitted to lay mines. France was not well prepared with mines. The mine was a weapon of strategic value, but was of too uncertain a nature to be used in a fleet action. It was, however, a useful tactical help to a small force and was, of course, a valuable anti-submarine weapon. During the war our use of mines was not confined to anti-submarine work, but extended to harassing the enemy in various ways and blocking his ports. In the early days of the war German mines were laid by surface craft, but after the first few months they were practically all laid by submarines.

Mines could be divided into controlled and non-controlled types. The first type were under human control, but the second, after once launching, could be removed only by sweeping, although they might be designed to become non-operative after a certain time either by flooding or sinking. Controlled mines had to be connected to the control station by an electric cable, which limited their application. If a mine could be designed to be controlled without a connecting cable it would be a valuable weapon. Mines could also be divided into contact and non-contact types, and anchored or drifting. The best mines for any particular purposes depended on the conditions. A contact mine would be not likely to waste itself, but for anti-submarine work, for instance, the probability of a contact mine being hit was too remote to make it a suitable weapon. The non-controlled anchored mine was generally the most practical application. The drifting mine was little used by us. British non-controlled mines would operate when the object attacked was 200 ft. away, and the percentage of failures was only 2 per cent.

For contact mines good data was now generally available. The firing gear suggested by Dr. Hertz in 1860 was probably still the best. Contact mines with this gear were used in the Russo-Turkish war of 1877. The value of contact mines had, however, been largely discounted by the development of non-contact mines. He could not describe the firing gear used in British non-contact mines, but might point out that the only two properties available by which an approaching vessel could be caused to actuate a non-contact mine were magnetism or hull vibration. The latter was a varying quantity, which the former was not, so that magnetism appeared a promising property to utilise. The apparatus actually used by the Admiralty was entirely of English invention and design.

As mines were weapons which were used lavishly in war, it was desirable that they should be of simple design from an engineering point of view. There was a great lack of data at the beginning of the war. As a mine might be moored for 12 months in 70 fathoms of water—that is, subjected to 200 lb. pressure—the question of a suitable jointing material was an important one, and had at first given some trouble. The production of non-porous castings and even the obtaining of suitable glass for the horns had also given difficulty in the early days. At the beginning there was also no information available in reference to guarding against corrosion. Questions of the best form for the mines had also to be tackled from the beginning. A current might force a mine below the depth for which it was set if it was not correctly formed, and so the whole question of shape had had to be studied. In connection with constructional matters even now the production of a reliable insulating material which could be moulded and would suit the conditions met in mines would be very useful.

Although we started the war so badly equipped in the matter of mines, we ultimately manufactured some 300,000. The greatest output reached was 10,000 a month. This figure was fixed, not by manufacturing capacity, but by the capacity of our mine-laying fleet. Including all makers of components, altogether 980 firms were engaged in the manufacture of mines. In 1918 mines cost about 70*l.* each, of which the amatol filling represented 24*l.* The Mark VII sinker cost 42*l.* The larger mine and M sinker, with a charge of 1,000 lb. of T.N.T., cost 200*l.* The present type of mine could be laid by any craft up to speeds of 15 knots. About four-fifths of our mine-layers were converted merchantmen, but a number of submarines were constantly engaged laying mines off the German coast. Had the war continued motor boats would have laid mines actually in German harbours. So far experience with mine-laying from aircraft had not proved very hopeful.

For dealing with German mines we had three methods—sweeping, the paravane and alteration in the structure of ships. Much had been done in the latter way, but no ship yet built looked on the mine with equanimity. Statistics on the subject were hard to get, but it was certain that mining had been a very important factor in our fight with submarines. A mine achieved a considerable part of its effect by moral and not by material means.

Professor Petavel was the only speaker on this paper. He said he would like to express his admiration for Commander Gwynne's paper and also for the work he had done in connection with the development of mines. Commander Gwynne had not made it clear to what a large extent development had been due to his own work. In 1914 we were hopelessly behind in mining work, but Commander Gwynne organised a scientific department, which first produced the paravane and later types of mine which could be constructed commercially and on a large scale. The later mines proved very efficient against submarines. Shortly before the Armistice a large barrage of non-contact mines was laid—that, is, mines which exploded when a submarine came within effective range, but did not necessarily touch the mine. A great debt was due to Commander Gwynne and others connected with the Portsmouth staff who carried out this work.

### The Paravane.

The next paper was one by Mr. R. F. McKay, entitled "The Paravane." It was read by the author. The paper, which was illustrated by means of cinematograph films, was listened to by a very large audience, and formed a most successful contribution to the proceedings of the Engineering Section. We reprint this paper in full in the present issue, and, as there was no technical discussion on it, it is unnecessary for us to summarise it here.

Professor Petavel at the conclusion of the reading of the paper congratulated the author both on the success of his paper and of his work in connection with the paravane. He (the speaker) had had something to do with early experimental work on the paravane, but at that time it was far from the successful appliance ultimately produced by Commander Burney and his associates.

### Conductivity of Heat Insulators.

The next paper was one by Professor W. M. Thornton, entitled "The Thermal Conductivity of Heat Insulators." It was read by the author. The paper stated that the thermal conductivity of metals had been adequately explained by the electron theory of matter. In the case of insulators the argument did not hold, and the mode of conduction in substances such as quartz or wax had not been worked out. There was a simple relation between the coefficient of thermal conductivity $k$, the density $\rho$, and the velocity of sound V, in a solid, which threw much light on the process. It was that $k = V^3\rho^3$, and since $V^2 = E/\rho$, where E is the elasticity, $k = E.\rho$. These relations held for all true solid insulators, but not for indiarubber or cork, which had peculiar elastic properties. For example:—

| Material. | Density. | Elasticity. | Velocity of Sound. | $E\rho$. | $V^3\rho^3$. | $k$. |
|---|---|---|---|---|---|---|
| Flint glass .. | 2·9 | $4{\cdot}8.10^{10}$ | $4{\cdot}1.10^5$ | 14·1 | 14·1 | 14·3 |
| Graphite .. | 2·3 | 5·25 | 4·65 | 12·1 | 11·5 | 12·0 |
| Paraffin wax | 0·91 | 0·154 | 0·13 | 0·14 | 0·14 | 0·141 |

From the kinetic energy of vibration $\frac{1}{2}mv^2$ it was found that the ratio of the velocity of sound to the velocity of atomic vibration by which heat was transmitted in insulators was $2{\cdot}9.10^{10}$. It was shown that the coincidence of this with $v$ could be explained and a reason given for the rule $k = V^3\rho^3$ by simple electro-magnetic consideration. The rule was a useful test for a heat insulator; the chief qualification is that it should be light and inelastic. The statement that it should be inelastic was, the author thought, a new contribution to this subject.

Mr. A. Lupton, discussing the paper, said that 50 years before he had given evidence before the Royal Coal Commission on the conductivity of rocks. Such rocks as lay around the coal measures were inelastic, but of considerable density, and apparently, according to the paper, should not be good heat insulators.

Professor Petavel said it was a great advantage to the Engineering Section to have fundamental physical questions brought before it from time to time, and he wished to thank Professor Thornton for his paper.

Professor Thornton, replying to Mr. Lupton, said that there was not time then to deal with the matter more fully, but he would say that the properties of all shales and coal measure rocks

# THE BRITISH TANKS USED IN THE WAR.

(*For Description, see opposite Page.*)

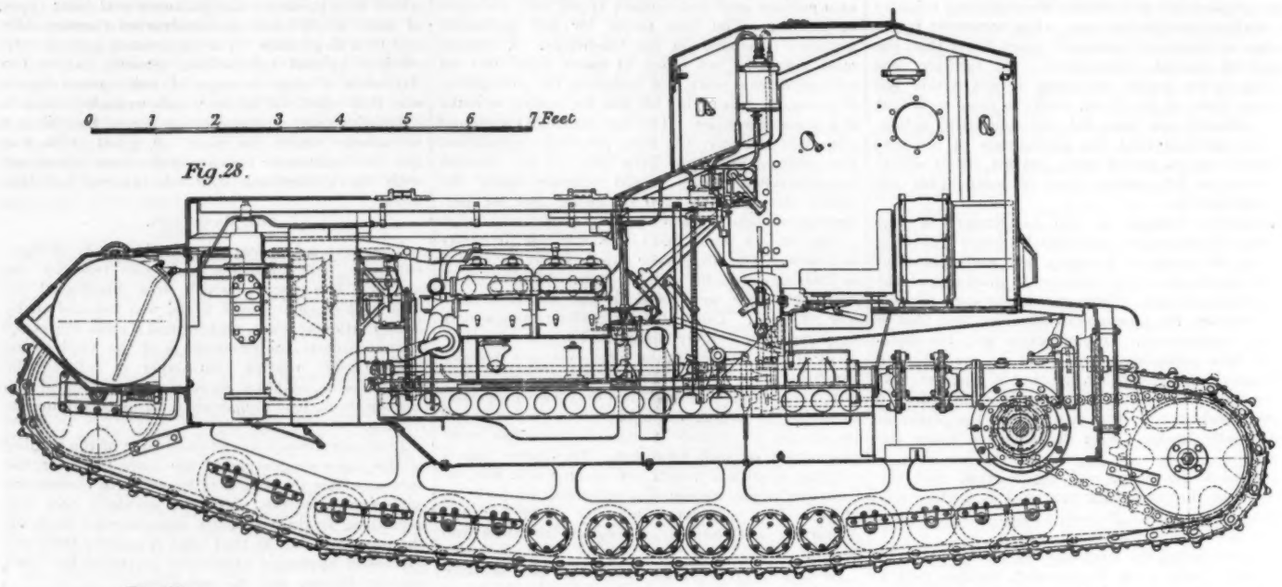
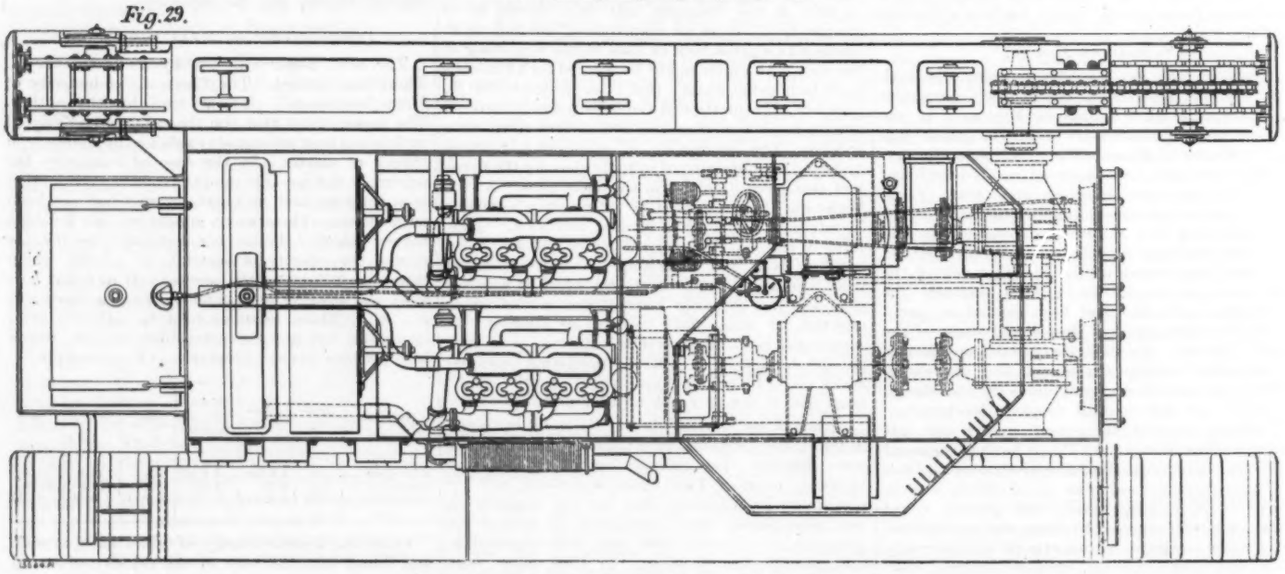



*Fig. 28.*

*Fig. 29.*



Figs. 28 and 29. Medium Mark A Whippet Tank.

fitted in properly with the theory he had brought forward.

### The Heating of Buildings.

The final paper of the morning and of the session was one by Professor G. H. Bryan, entitled "The Application of Aerofoil Theory to the Heating of Buildings." In view of the lateness of the hour Professor Bryan gave only a brief summary of his paper. He said its idea was to suggest that some of the cut-and-dried theoretical work which had been done in aerofoils might have a practical application in connection with the heating of buildings. The immediate suggestion was that in the case of a radiator fixed directly below a window (as was so frequently done) the major part of the heat given out went through the window and did nothing towards warming the room. He had fixed a flat plate at an angle and sticking out from the wall over a radiator below a window, and found that it made a wonderful difference in the warmth of the room. It was important that the plate should be fixed at the correct angle and that its outer edge should be sharp. The theory was that the plate induced a steady flow of hot air round its outer edge and into the room. One obtained a dead bank of cold air above the plate and next to the window, which was just what was required.

Professor Watkinson said he was disappointed in the paper. Professor Bryan had told nothing of the application of the aerofoil theory to the heating of buildings, and had merely brought forward the old idea of a deflector, which was frequently used—to prevent discoloration of wall, for instance.

Professor Thornton asked if in the application of theory to practice Professor Bryan would not find great difficulties owing to variation in the density of the air.

Professor Bryan, in reply, said that he proposed to work out the matter at first from the point of view of constant density and see the result. In reply to Professor Watkinson, he thought the purpose of his paper had not quite been understood. Professor Watkinson had no doubt seen various deflectors of various shapes at one time or another. His point was that, if the correct shape was worked out from theoretical considerations, a much better effect would be obtained than was got now.

Professor Petavel then thanked Professor Bryan for his paper, and thanked again all who had worked for the success of the meeting.

In the afternoon a visit was paid by the Section to the Winton Aerodrome of the Bournemouth Aviation Company.

(*To be continued.*)

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Royal Mint at Melbourne.—Some interesting details of the operations of the Victorian branch of the Royal Mint at Melbourne have recently been made available. The Mint was established in 1872, and, according to the latest returns, 37,300,120 oz. of gold have been received, the coinage value of which has been 146,628,219*l*. Of the gold received 27,588,775 oz. were raised in Victoria, and the balance in New Zealand and Western Australia. The output has consisted of 134,813,500 sovereigns, 1,893,559 half-sovereigns, and 2,606,206 oz. of gold bullion, the total value of coin and bullion being 146,632,904*l*. The Melbourne Mint has been coining silver as well as gold since 1916, and up to the end of last year the number of silver pieces coined was 31,484,806, of a total value of 1,842,150*l*.

# THE BRITISH TANKS USED IN THE WAR.

*Fig 30.*

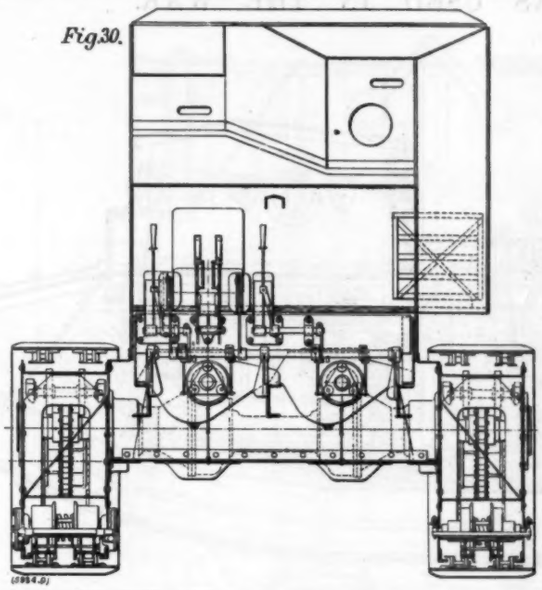


FIG. 30. MEDIUM MARK A WHIPPET TANK.

## ACCOUNT OF THE BRITISH TANKS USED IN THE WAR.*

By Sir EUSTACE H. TENNYSON D'EYNCOURT, K.C.B.
Director of Naval Construction, the Admiralty.

(*Concluded from page* 339.)

### MEDIUM MARK A WHIPPET TANK.

Whilst Marks IV and V were being developed and manufactured the question of obtaining a lighter tank with a smaller armament and crew was investigated. Many people considered that there were great possibilities for a faster tank in an advance. Sir William Tritton took up this idea with great keenness, and the development of the whippets was chiefly due to him. Various experimental machines were tried and showed great promise, and finally a design of medium Mark A was decided on.

From the general arrangement drawings, Figs. 28 to 30, annexed, and the perspective view, Fig. 50, on page 376, it will be seen that this tank is quite distinct in design both as regards hull and transmission from the previous marks. The dimensions are given in the table on page 337 *ante*. The improvements were :—

First : Increased speed, double that of heavy tanks.
Second : One-man control.
Third : Decreased ground pressure.

The increased speed was obtained by a very considerable reduction in the weight of the machine, which was only 14 tons as compared with 28 tons of the previous types. The method of clearing the mud from the track by having mud chutes the full length of the machine, and the use of top rollers, considerably decreased the friction of the track. Each track was driven independently, two independent engines and sets of transmission gear being used.

*The Engines* consisted of two 4-cylinder Tylor engines, giving 45 h.p. each. These were connected by cone clutches to gear-boxes of the constant mesh type giving four speeds forward and one reverse, and driving through worm reduction gears to chain drives, direct to the track sprockets. The sprocket driving pinions, which caused so much trouble on the other types of machine, were omitted.

*Steering* was controlled by running one engine faster than the other or disconnecting it by one of the clutches.

These tanks were built in 1917-18 and were first used at the front in 1918 and did very good execution among the enemy. They first appeared about the same time as the Mark V, and the reports of the Germans showed that the appearance of tanks of these two types had had a very marked effect upon their nerves. Many of the German Army Orders issued were almost of a frenzied character, and on several occasions reports from regimental commanders showed that they considered that, when faced by the tanks, they could not be expected to stand up to the attack any further ; in fact, the tanks being in front of them was sufficient excuse for surrender.

### MEDIUM MARK B WHIPPET TANKS.

Further development of the whippet, or lighter tanks, resulted in modification of this form, and the general arrangement is shown by Figs. 31 to 33, page 372, and by the perspective view, Fig. 51, on page 376. Dimensions, &c., are as in other cases given in the table on page 337, *ante*.

* Paper read before Section G of the British Association, at Bournemouth, September 10, 1919.

The total weight in fighting trim was 18 tons—the overall length being 22 ft. 9½ in.—the track outline of machine was similar but on a smaller scale to the heavier types of machines. By placing the engine further back in the machine an improved fighting chamber was obtained which, with the turret, provided ample head room. The machine guns were placed in this turret in a similar way to the Mark VIII, to be described later, firing over the tracks.

An improved arrangement of track rollers was introduced into this machine, the rollers being narrow and staggered ; greater number of supports for the track were provided. More top rollers and mud chutes were provided to improve the cleaning of the track from mud. The engine was a 4-cylinder 100 h.p. Ricardo engine. It was connected by a plate clutch to a four-speed gear-box and thence by bevels to the cross shaft which drove the steering epicyclic gear in a similar way to the Mark V machines. The power was taken from the epicyclic gear by the duplex driving chains direct to the track driving sprockets.

### MARK VIII TANK.

A great deal could be written about the production of tanks from the time when a number were first ordered to the end of the war. At a time when all the engineering establishments and facilities in the country were absorbed to the limit, there was great difficulty in placing orders for a new type of engine of war. Colonel Stern—now Sir Albert Stern—who was made President of the Tank Supply Committee early in 1915, displayed extraordinary energy in pushing forward the manufacture of the tanks. He overcame all the difficulties of placing the orders and inspired the manufacturers with tremendous enthusiasm and zeal to get the largest number of tanks completed at the earliest possible moment, and there is no question that it was chiefly due to his energy that such large numbers were produced in 1917. In April of that year the Americans having come into the war, they took up the tank idea with great energy. The late Ambassador, Mr. Page, had, early in the year, been shown a demonstration of our tanks, and he wrote to Washington strongly recommending the adoption of tanks by the American Army. As the whole subject was entirely new to them, it was decided to start an Anglo-American Commission for the production of tanks jointly, and Colonel Stern was transferred from the English Tank Supply Department and made British Commissioner on the Anglo-American Commission. The arrangement was that a tank was to be designed, parts of which could be made most conveniently in this country and parts in America ; and the whole was to be assembled at a specially-constructed factory in France. Generally, the British were to supply the hull and a good deal of the armament, and the Americans were to supply the engines and certain parts of the gear. A special tank was designed with all the latest improvemsots to suit these arrangements and was called Mark VIII. It was rather a larger machine than any of the previous tanks and had the engine in an entirely separate compartment from the general interior of the tank, which was occupied by the officers and guns' crews. This was a great improvement, as in some cases when the tanks were hit by shell, the whole tank was set on fire, the engine being in the middle and not divided off. This trouble was obviated in the design of Mark VIII. Otherwise the design was generally on the principle of the Mark V, with two 6 pdrs. in sponsons which were arranged to hinge inboard for transportation. A considerable time was taken in developing the Liberty engine to make it suitable for the Mark VIII tank ; and the production of the Anglo-American tank was only just beginning when the Armistice was signed.

Detailed drawings of Mark VIII are reproduced in Figs. 34 and 35 on plate XX, and by Figs. 36 to 38 on page 373, while a perspective view is given in Fig. 52 on page 376. The dimensions, &c., are given in the table on page 337, *ante*.

The following are the chief features of this type of machine :—

(1) Increased length, viz., 34 ft. 2½ in., *i.e.*, 7 ft. 9½ in. longer than previous machines giving increased trench crossing capacity.

(2) Conditions for the crew were considerably improved by partitioning the fighting chamber in front of the machine from the engine room at the rear of the machine by a bulkhead. The fighting chamber by means of ventilating fans was kept at slightly above the atmospheric pressure of the engine room, so preventing the fumes or heat of the engines from entering the fighting chamber. The possible danger of fire spreading from the engine room to the fighting chamber was also reduced.

(3) The space in the fighting chamber being clear of engine or machinery gave better space for the crew and allowed for better control of men by the commander.

(4) The power of the engine was increased to 300 h.p., giving a greater power per ton weight of machine, so permitting higher average speed.

(5) The track pressures were kept low, being considerably under that of previous machines.

(6) The sponsons were hinged and the weight taken on roller bearings so that they could be moved in and out by hand from the inside of the machine in a few minutes.

*Engines.*—The machine was designed to take alternatively the Liberty 12-cylinder Aero engine or the 12-cylinder 300 h.p. Ricardo engine, both engines running at 1,400 r.p.m.

The power from the engine was taken through a coil clutch and connected to the cross shaft by means of the reversing bevels. Two two-speed epicyclic gears were used, one on either side of the bevel gears on the cross shaft. These epicyclic gears were controlled by hand levers from the driver's seat by brake bands. By this means the speed of the tracks could be controlled individually for steering or both together for changing the speed of the machine. From the cross shaft chain drives take the power to a roller type driving pinion operating on the track sprockets. The track links were of larger design than those used on all other machines being 11·1 in. centres instead of 7½ in. centres and the track sprockets and front track adjusting wheels were increased in diameter proportionately.

Track shoes were made of thinner armour plate, 8 mm. instead of 10 mm.—were 26½ in. wide in order to obtain the necessary strength—were dished and the edges turned up to allow for easy steering. Twenty-nine pairs of rollers supported the machine on each side, the track being carried above the machine on rails and one pair of rollers on each side. Extra large mud chutes were provided.

Mark VIII* was designed but not put into production, having an overall length of 44 ft.

### SPARE PARTS.

There were a great many difficulties to overcome throughout the whole undertaking in the supply of spare parts of all kinds. The wear and tear on certain parts which were very heavily stressed was very great, and the mud of Flanders and some parts of France was a great enemy of the tanks. The mud got into the gears and the wear and tear of the sprocket and pinion wheels especially was very serious, and at a very early stage we had to take special steps to try and improve this. The dimensions and arrangements of the teeth of the wheels had to be modified, and the material also had to be improved and a much tougher metal used than in the early tanks. This resulted in greatly reduced wear and tear and also kept down the repairs. However, throughout the whole time the renewals and repairs were a very serious matter, involving very hard work and large establishments at the front for dealing with them. Shops were erected and special training given to men engaged at the repair bases, and a wonderful amount of work was done and organised in a satisfactory manner by the Tank Corps. This is not the occasion to go into the work of the Tank Corps, which became one of the most splendid bodies of men in the Army, but I cannot pass over the matter of repairs and the work done on the engineering side without a tribute to all who carried it out so well.

### TACTICS AND STRATEGY.

There are certain general considerations regarding the application of tanks to tactics and general strategy, to which I think reference might be of interest.

First, the primary consideration is that they provide mechanical means for carrying out, with a small number of men, work which without them would require a much larger number of infantry ; even a large force without tanks might often through great loss of life, physical exhaustion or other causes, be prevented from advancing and obtaining their object. Just as in sea warfare, one modern warship with a crew of a few hundred men is the equal of a large number of ships or boats of older type without modern mechanical appliances and armaments, so an Army provided with tanks and a comparatively few men is the match for a much larger force without tanks.

It has been clearly shown in this war that tanks can advance without artillery preparation—thus saving the expenditure of shell as was required to cut the wire in the early days of the war before tanks appeared. Literally, millions of shell were required for the conquest of a given

# THE BRITISH TANKS USED IN THE WAR.

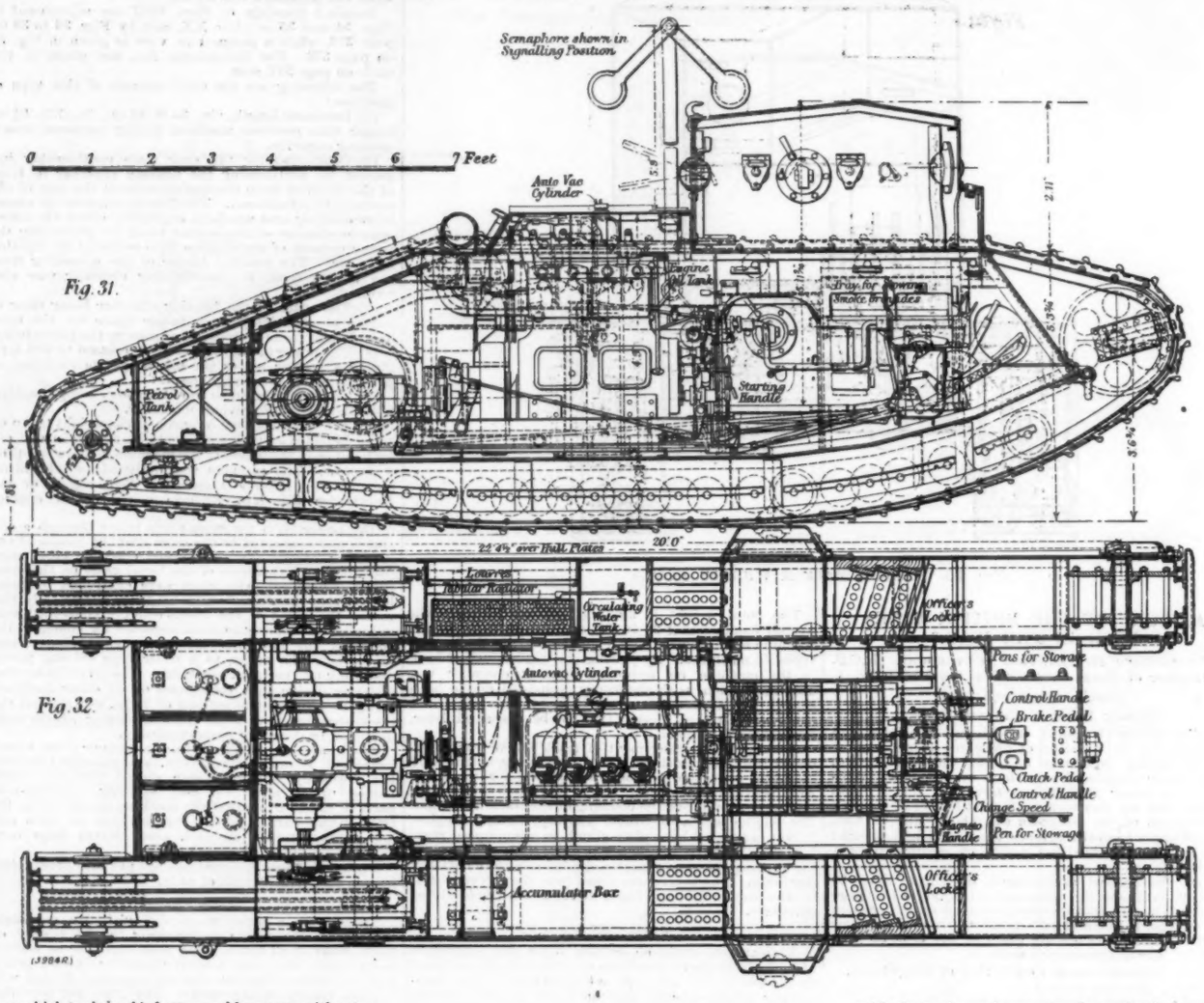



Fig. 31.

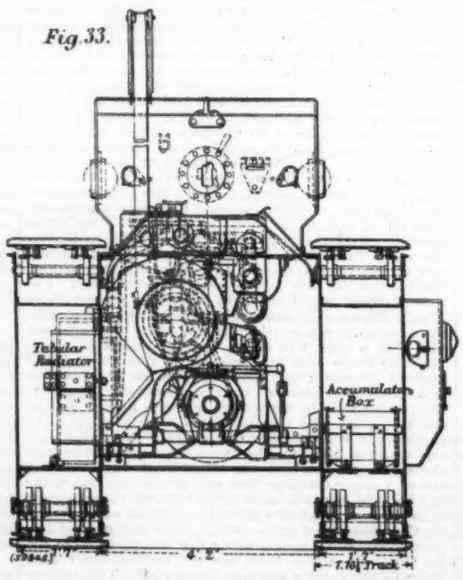
Fig. 32.

area which tanks and infantry could conquer without artillery preparation. The artillery preparation, of course, took a long time—perhaps days or weeks, and gave full warning to the enemy of what he had to expect and the probable locality of the attack.

As to the moral influence, there is no question that tank attack had in all cases the most demoralising effect upon the enemy, and correspondingly an encouraging stimulus on our own men, who felt that they were being provided with engines of war which, whilst saving their own lives, terrified and destroyed the foe, obliterating machine guns, wire and other obstructions, and enabling an advance to be made in comparative safety. The Germans also, no doubt, lost heart, for they felt that the old story of their Army being provided with the best possible equipment and having a general superiority of weapons was no longer true, and they naturally asked why they had not tanks.

There is another aspect of the advantage of tanks which also became very apparent, and that is the possibility of carrying up the supplies of ammunition, &c., right into the first lines; even infantry could also be taken up. This is one of the most difficult problems of modern war, and the tanks to a great extent solved it. In the early stages of the advance, the ground in most cases had been rendered impassable in the ordinary sense of the term, and until roads and railways were completed no great quantities of supplies could be carried forward. Napoleon's dictum that an Army moves on its belly was doubly true in the Great War when every road was shelled, every bridge broken down, and the ground so torn that it took a long time to restore the conditions for a further advance to be made. Now, the tank to a great extent does away with the necessity of regular roads or railways. Subject always to the limitations created by very mountainous country, great rivers or marshes, the whole country becomes the tanks' highway, just as the sea is the highway for ships. This, of course, is a tremendous tactical, and indeed, strategical, point, and modifies the whole military outlook, so that

Fig. 33.




FIGS. 31, 32 AND 33. MEDIUM MARK B, WHIPPET TANK.

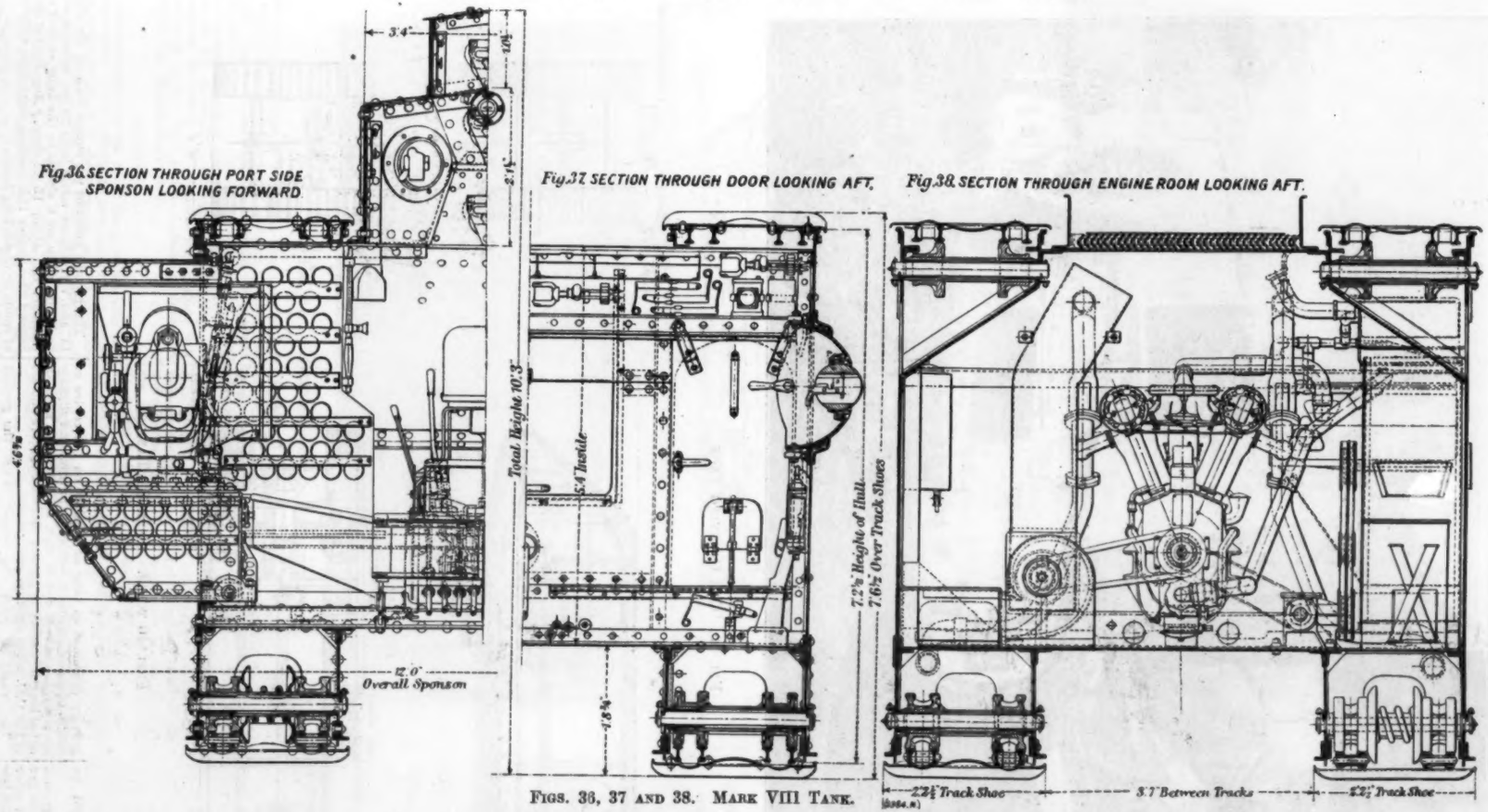
with the tanks we have not only mechanical means to a great extent replacing flesh and blood, but with their opportunities of overcoming natural obstacles we have a mechanical appliance which obliterates to a great extent the natural obstacles which have hitherto been sufficient to stop the ordinary methods of locomotion.

### SPECIAL TANKS.

A very large number of the Mark IV and later tanks were manufactured by the Metropolitan Wagon and Finance Company at Oldbury, and Major Gregg, who belonged to the Metropolitan Company, and who had been at the front with the artillery in the early days of the war, took a keen interest in the tanks and suggested a gun-carrying tank which should be able to take up fairly heavy artillery in an advance. Tanks to perform this function were accordingly designed and a certain number constructed. These tanks were able to carry either a 4·5-in. howitzer or a 6-in. howitzer, arrangements being made quickly to place the gun on the tank and to dismount it when it arrived at the desired position, when the gun-carrier tank could return for another gun or for more ammunition. These gun-carrier tanks were able to carry a considerable number of rounds and were finally used more for the purpose of bringing up ammunition than for actually carrying a gun. The perspective view, Fig. 39, page 374, shows that the design differed from the Mark IV in many particulars; the track passed through a tunnel and not overhead as in the other tanks, and a good deal of trouble was experienced with mud collecting in the tunnel. It was possible to fire the gun or howitzer from the tank itself without dismounting it, but it was not proposed to do this in practice and it is not thought that it was ever actually done in action. A considerable number of Mark IV tanks were also converted into supply tanks.

Certain tanks were also adapted for bridging purposes and special appliances fitted; others had cranes fitted for salving disabled tanks;

# THE BRITISH TANKS USED IN THE WAR.




FIGS. 36, 37 AND 38. MARK VIII TANK.

some, too, were fitted with trench mortars and other devices.

### MARK IX TANK.

Mark IX tank, which is illustrated by Figs. 40 to 43, on page 374, and perspectively by Fig. 53, on page 376, was specially designed for carrying infantry or supplies. It is capable of transporting a net load of 10 tons or party of 50 men. The length was increased to 31 ft. 11 in. and a maximum cargo space was arranged by moving the transmission gears to the extreme rear of the machine and the engine as far forward as possible. By this means a clear cargo space of 13 ft. 6 in. long in the centre of the machine, by 5 ft. 5 in. wide, was available; four large doors arranged in the sides of the machine allow of easy access for loading. The engine, gear-box and epicyclic gear were similar to those of Mark V and the final drive arranged by a special type of roller chain direct to the track sprockets.

### FRENCH AND GERMAN TANKS.

It should be mentioned that the French were developing tanks about the same time as ourselves and we were in close communication with them on the subject throughout the whole development. The French tanks were on somewhat different lines from our own, but space prevents my going fully into any account of these. The French heavy tank was never so fully developed as our own, but their light Renault tank, which was much smaller even than our whippets, was built in great numbers and was used very successfully during the last year of the war. These Renault type tanks only weighed about 5 tons. They carried a 37 mm. gun, and machine guns, and had a crew of three men. In order to afford comparison of the French tanks with our own, views are given in Figs. 44 and 45, page 375, of a Renault tank. Marshal Foch himself took a great interest in tanks, and paid a special visit to our ground, near London, to see a display of our tanks in October, 1917, and was pleased with what he saw.

The Germans, when they first saw our tanks on the Somme in 1916 were completely surprised. The comments in their papers were very interesting. Almost in the same breath they said they had invented them, that they were no use and that it was a barbarous invention to use such machines in warfare. They seem to have done very little to develop their own tank designs after this, although they did what they could, and they went through all the troubles that we experienced and met with great difficulties, many of the parts being almost impossible to obtain in Germany. They finally produced a heavy tank with armour about 1 in. thick, but it was of a very cumbersome type and suffered from the defects of our earliest efforts and was, in fact, a very primitive attempt compared to our Mark IV's or later tanks. They made no great number, and the ones they did make did not do much execution; in fact, their best tank units were composed of tanks which they had captured from the British. Fig. 46, page 375, show the general arrangement of a German tank, while Fig. 47 is a photographic view.

The anti-tank devices used by the enemy consisted, first, of deep and wide trenches, and, secondly, of artillery, which were in the later stages of the war specially told off to deal with the approach of tanks and not to fire with any other object whatever. These specially allocated guns were probably the most efficient anti-tank device the enemy had. They always used their machine guns against tanks, and whenever possible they were provided with special armour-piercing bullets. These were able to pierce the thinner armour of our tanks, but our later editions had thicker armour which was impervious to the German machine-gun bullets. They then started special anti-tank rifles with abore of about ½ in. These were practically an ordinary rifle on a larger scale and were fired from the shoulder, and with armour-piercing bullets these did a certain amount of execution among our tanks; but they were not favourites with the German soldier, as the "kick" was very heavy and generally knocked the gunner down. Other devices were used, namely, mines, some of which were composed of ordinary artillery shell with special arrangements for firing when the tank passed over them. The best obstruction, however, to the tank was finally considered by the Germans to be to have a river or marshy ground in front of their lines.

### EXPERIENCE WITH TANKS.

It is not possible within the scope of this paper to go into all the special minor items used with our tanks; but there were special arrangements for signalling, for creating smoke-screens, and all the minor details, such as the special bullet-proof spherical mountings for the machine gun, towing arrangements, unditching gear for use with the tanks over very bad ground, and special arrangements termed "spuds," which were devices on the tracks for helping them on soft ground; but, as I said, it would take too long to go into all these in any

# THE BRITISH TANKS USED IN THE WAR.

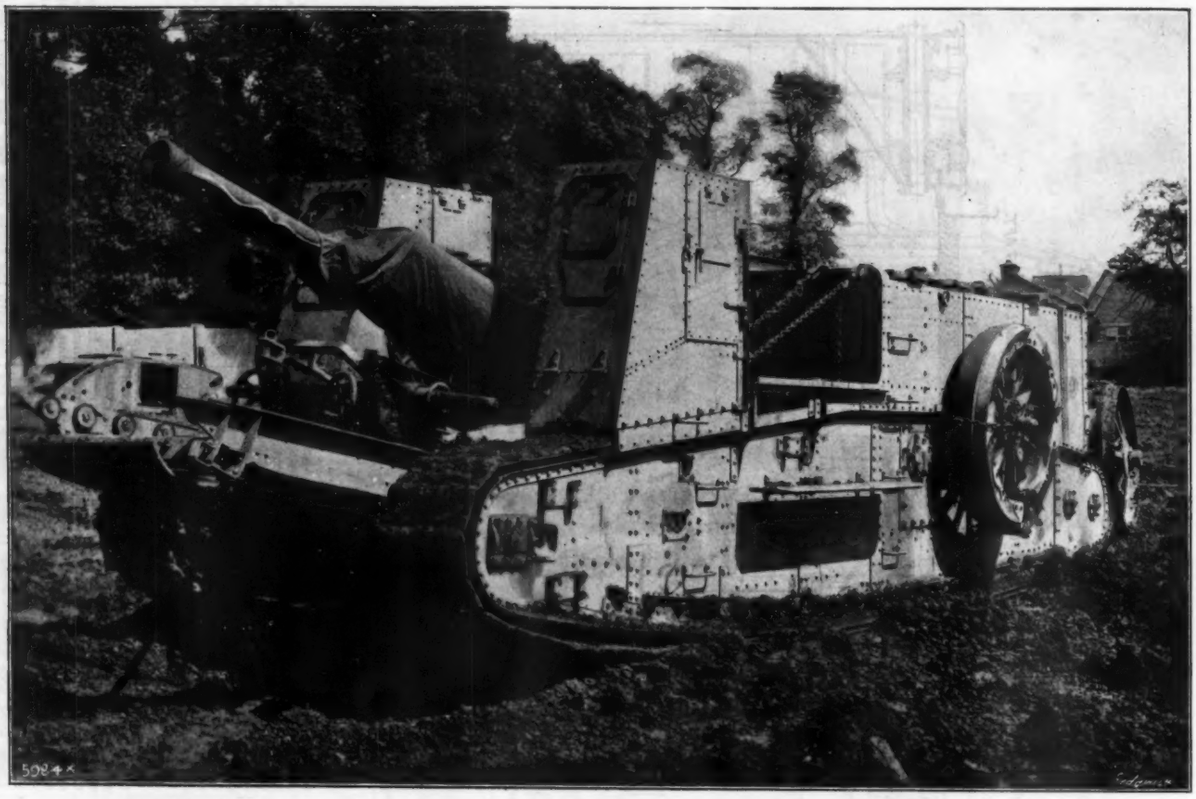
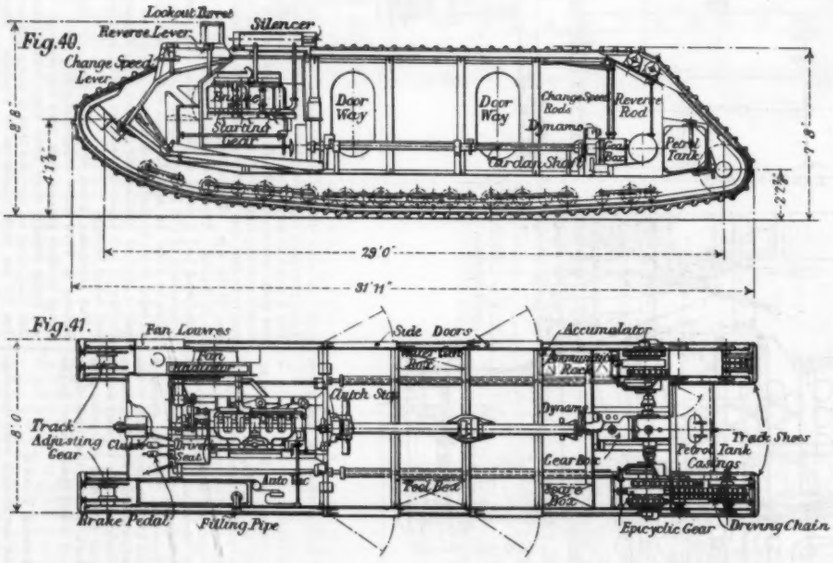
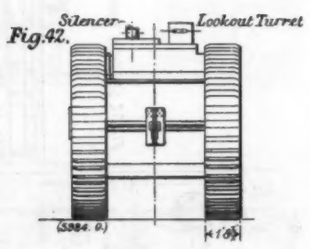


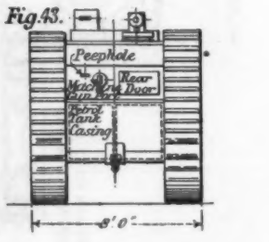
FIG. 39. GUN CARRYING TANK.










FIGS. 40 TO 43. MARK IX TANK.

detail. In this connection the following should be noted :—

The area of the track in contact with the ground and the weight of the machine fixes the pressure per square inch which the ground has to support, or in other words the degree of softness of the ground over which the machine can pass.

The bottom outline of the Tank is arranged so that the arc of track contact increases rapidly as the machine sinks into the mud. The track is flat under the centre of gravity (which is as near as possible on the centre of length of machine) and is carried up in front and slightly up towards the rear end in such a curve as to keep an equal length of track in ground contact both fore and aft of the C.G. when sunk on soft ground.

The length of track in contact with the ground considerably limits the ability of the machine to steer as the tracks have to be skidded sideways over the ground, and power necessary to do this when the tracks have sunk into the ground is considerable.

The ground pressure per square inch on the Mark I, IV and V machines varies from 28 lbs. without sinkage to 11 lbs. when sunk almost to the belly or floor of the machine, *i.e.*, about 15 in. deep. Any further sinkage beyond this makes the machine immobile without use of spuds or unditching beam.

Owing to the condition of the ground in Flanders it became necessary to decrease the track pressure, and the tracks were increased in width from 20½ in. to 26½ in., and in some of the later machines the ground clearance

# TANKS USED IN THE WAR.

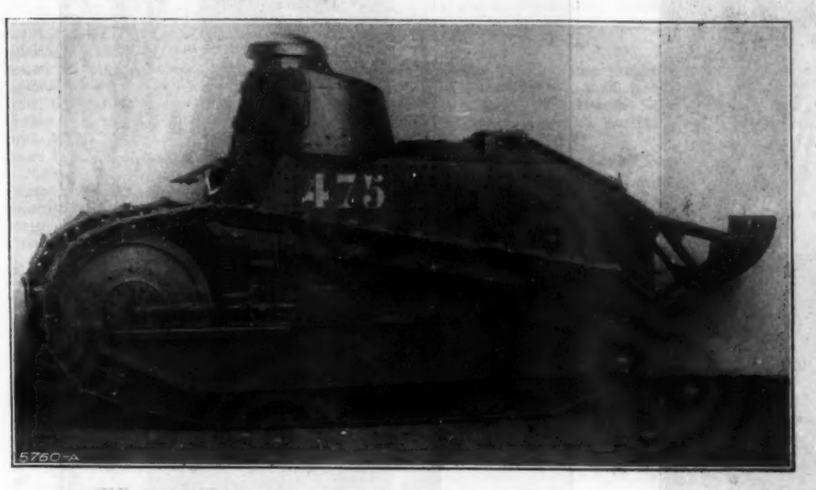



FIG. 44.

FIG. 45.

FIGS. 44 AND 45. FRENCH TANK OF THE RENAULT TYPE.

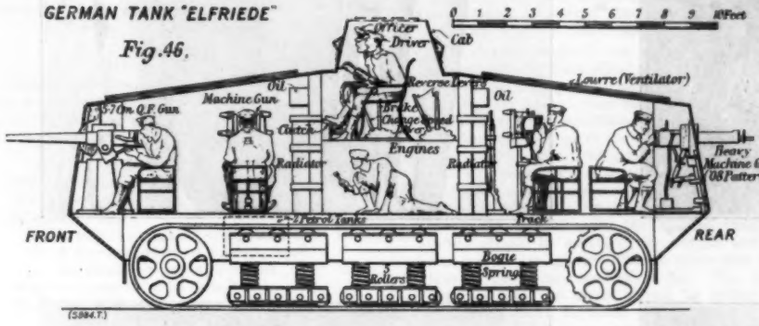
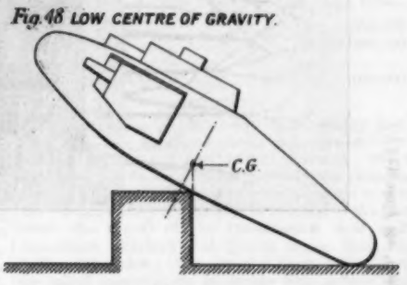
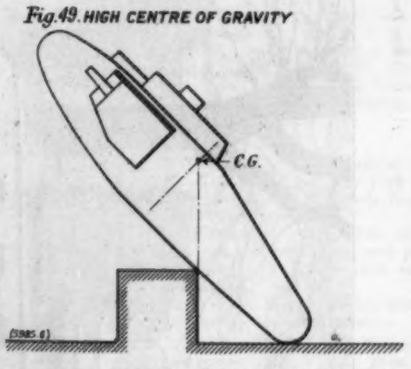


FIG. 47. A GERMAN TANK.




MACHINE SHOWN AT POINT OF BALANCE IN BOTH CASES.




gave a possible sinkage of 1 ft. 9 in. In some of the later machines a minimum track pressure of 5 lbs. was attained, which is less than that under the average human foot.

An important point in design is to keep the centre of gravity as low as possible, so that when climbing out of a trench or over a high obstacle the machine will balance over easily. This will be understood from the diagrams Figs. 48 and 49 annexed.

### CONCLUSION.

I must apologise for the paper being rather long and perhaps crude. It is difficult to give an account of the whole undertaking in a short space, and as it is an engineering paper I have not given much account of any operations, interesting as such an account might be and full of incident, but I hope my paper may be of some interest to the Engineering Section of the British Association; and I cannot help thinking that it should be a source of satisfaction to the engineering fraternity of this country that in addition to the enormous advances which have been made in aviation, in artillery, and in almost every branch of engineering for war purposes, we should have been able after the war commenced to produce an entirely new engine of warfare which without doubt produced a marked effect on the campaign and came as a complete surprise to the Huns, and showed that our engineers were able to assist our splendid troops by mechanical appliances which finally gave them a superiority over the enemy.

In conclusion, I think it will be impossible to give a better summary of the work of the tanks during the later periods of the war than that given by Sir Douglas Haig, the British Commander-in-Chief, in his dispatch dated December 21 last, which I quote below:—

*Quotation from Sir D. Haig's Dispatch, dated December 21, 1918.*

"In the decisive contests of this period, the strongest and most vital parts of the enemy's front were attacked by the British, his lateral communications were cut and his best divisions fought to a standstill. On the different battle fronts 187,000 prisoners and 2,850 guns were captured by us, bringing the total of our prisoners for the present year to over 201,000. Immense numbers of machine guns and trench mortars were taken also, the figures of those actually counted exceeding 29,000 machine guns and some 3,000 trench mortars. These results were achieved by 59 fighting British Divisions which in the course of three months of battle engaged and defeated 99 separate divisions.

"Since the opening of our offensive on August 8, tanks have been employed in every battlefield, and the importance of the part played by them in breaking up the resistance of the German infantry can scarcely be exaggerated. The whole scheme of the attack on August 8 was dependent upon tanks, and ever since that date on numberless occasions the success of our infantry has been powerfully assisted or confirmed by their timely arrival. So great has been the effect produced upon the German infantry by the appearance of British tanks that in more than one instance, when for various reasons real tanks were not available in sufficient numbers, valuable results have been obtained by the use of dummy tanks painted on frames of wood and canvas.

"It is no disparagement of the courage of our infantry or of the skill and devotion of our artillery to say that the achievements of those essential arms would have fallen short of the full measure of success achieved by our armies had it not been for the very gallant and devoted work of the Tank Corps, under the command of Major-General H. J. Elles."

Finally, I should like to take this opportunity of thanking Lieut. Rackham for the assistance he has given me in preparing the plans and tables of particulars given in this paper.

# BRITISH TANKS USED IN THE WAR.

(*For Description, see Page* 371.)

FIG. 50. MEDIUM MARK A WHIPPET TANK.

FIG. 51. MEDIUM MARK B WHIPPET TANK.

FIG. 52. MARK VIII TANK.

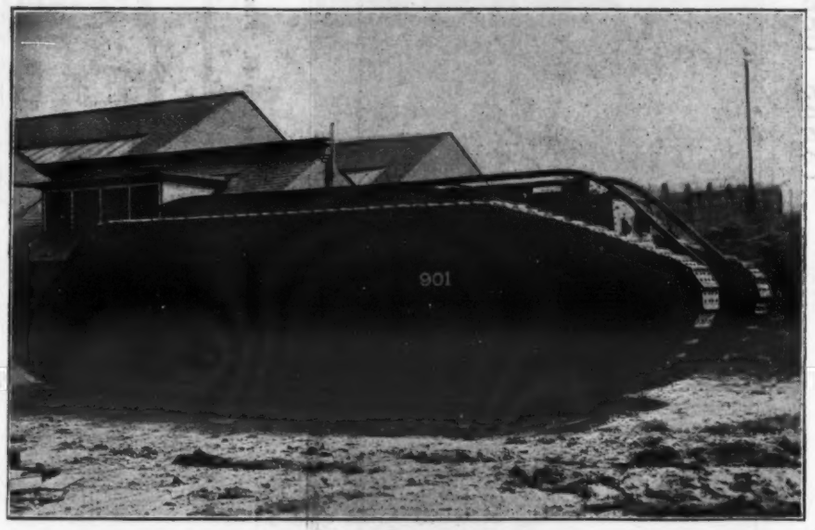



FIG. 53. MARK IX TANK.

## INDUSTRIAL NOTES.

ON Monday last, a Royal Proclamation was issued, the text of which is as follows :—

"We, having learned that many men returned from service with Our Navy, Armies and Air Forces, disabled, whether by wounds or physical afflictions, have not yet found a permanent means of livelihood, and being persuaded that it is a clear obligation upon all who now, through the endeavours of these men, under the mercy of Almighty God, enjoy the blessing of victory and peace, to make acknowledgment of what they have suffered on our behalf;

"Now, therefore, We have thought fit, by and through the advice of Our Privy Council, to issue this Our Royal Proclamation, most earnestly charging all those of Our loyal subjects, being employers of labour, that they do bind themselves to take into and keep in their service as many men, being thus disabled, as their several businesses will allow, not being held back in their performance of this high and solemn obligation either by fear of inconvenience or loss, but rather omitting nothing which will secure that occupation be found without delay for all these whose lack of employment would offend the general conscience;

"And to this end We have signified Our will and pleasure that the National Roll of those who undertake to employ such men, in accordance with the plans prepared by Our Ministry of Labour, shall be styled and known as the King's National Roll;

"And We do hereby exhort all ministers of religion, in their respective churches and chapels within Our United Kingdom of Great Britain and Ireland, to read or cause to be read this Our Proclamation, on such convenient days as may be arranged after the issue thereof.

"GEORGE R.I."

---

A paper entitled *The Future*, which was distributed free throughout the country last Monday, gives the Government's Statement on National Needs and National Policy. It states the Government's Autumn Programme, as follows :—

LABOUR.

A national maximum 48-hour week.
A living wage for all workers.
Workers to have—
(*a*) A voice in working conditions.
(*b*) A financial interest in their work.
(*c*) Provision for unemployment.
Whitley Councils to be developed.
Healthy houses and expeditious transport.

COAL MINES.

State purchase of mineral rights.
A levy on purchase price for social amelioration of mining areas.
Miners to help shape conditions of industry.
Reorganisation and economical management of mines.
Labour representation on controlling boards of mining area.
A free career to talent throughout the industry.
A committee on output to be set up immediately.

TRADE POLICY.

Free imports (with certain exceptions) from September 1, 1919.
No Government support of Foreign Exchanges except to prevent complete collapse.
No dumping of foreign goods for sale at sweated prices.
Powers to prevent any flood of imports competing unfairly with British goods through a collapse of exchange in the country of origin.
Protection for unstable "key" industries, *i.e.* :—

(*a*) Products essential for war.
(*b*) Industries so neglected before the war that there was an inadequate supply of their products.
(*c*) Industries which it was found necessary to foster and promote during the war.
(*d*) Industries that cannot maintain the level of production essential to the nation without Government support.

No undue profits at the expense of the community to be made by reason of protection of unstable "key" industries.
Development of technical instruction and research for all classes.
Inquiry and propaganda to promote increased output.
Standardisation to be promoted and co-ordinated by the State.
Development and control of electric and water power supply.
Imperial trade to be fostered and an Imperial Investigation Board to improve communication and transport within the Empire.
Exports credits to facilitate resumption of trade with disorganised European countries.
Stimulation of export trade.
Agriculture to be further developed, and fixed prices for crops to continue for another year at least.
Protection against trusts, combines and harmful trade combinations; Government to collect fuller statistics of national trade, prices, costs, profits, &c.

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The Trades Union Congress resumed its sittings on Wednesday, the 10th inst., when Mr. R. Smillie, president of the Miners' Federation, put forward the following resolution dealing with the nationalisation of mines :—

"This Congress having received the request of the Miners' Federation to consider the Government's rejection of the majority report of the Coal Industry Commission and the adoption in its place of a scheme of district trustification of the industry, hereby declares that in conjunction with the miners it rejects the Government scheme for the governance of the industry as a scheme contrary to the best interests of the nation, and it expresses its resolve to co-operate with the Miners' Federation of Great Britain to the fullest extent with a view to compelling the Government to adopt the scheme of national ownership and joint control recommended by the majority of the Commission in their report.

"To this end, the Congress instructs the Parliamentary Committee, in conjunction with the Miners' Federation, to immediately interview the Prime Minister on the matter in the name of the entire labour movement to insist upon the Government adopting the majority report.

"In the event of the Government still refusing to accept this position, a special Congress shall be convened for the purpose of deciding the form of action to be taken to compel the Government to accept the majority report of the Commission."

Mr. Smillie pointed out that 1,240 persons in the mining industry were killed every year, or 4 a day, and that 6,500,000 mine workers had been injured in the last twenty years. The miners were of opinion that this roll could be considerably reduced, but that there was very slight hope of its being reduced so long as the mines were worked for private profit and not for the good of the nation as a whole. In view of the fact that the mines are privately owned, and that output in the past has been the chief desire of the officials, it is inevitable, according to Mr. Smillie, that sometimes safety should be sacrificed for output and profit. It was not for the miners' interest alone that nationalisation of the mines was asked for. The miners were desirous that the mines should be better developed, that they should be made up to date, that machinery should take the place of hand labour in thousands of instances where at present men and boys were doing work that ought to be done by machinery.

The resolution was seconded by Mr. J. H. Thomas, M.P., secretary of the National Union of Railwaymen, who said that the railwaymen were as keen on State ownership of the railways as the miners were on State ownership of the mines, not simply because State ownership of the railways would be beneficial to themselves, but because they were satisfied that their own interest was consistent with and part of the interest of the State as a whole.

Mr. Havelock Wilson spoke against the resolution, and said that the direction in which the Congress was moving was detrimental to the best interest of the working people. The Post Office under State management had not been a success; the men employed in the Post Office had not been the best paid. The telephone system which was a paying concern before the Government took it over, was now a bankrupt concern. It was suggested that the miners when nationalised were to be managed by a "Big Ten"; but no less than 5,000 would be employed in the coal industry to help the "Big Ten." As to the statement that over 1,200 miners were killed every year, he would tell Mr. Smillie that out of only 250,000 seamen, over 2,000 were killed every year, and State control was more responsible for this than anything else. There was not a phase of the sailor's life which was not regulated by Act of Parliament in 1854, and as a result of so much dependence on the State, the sailors fifty years ago were reduced to the most abject form of slavery. It was only by the strong arm of their union that they had now some degree of freedom. The more State control the working men got the less their chance of freedom.

A card vote was ultimately taken, when there voted :—

| | |
|---|---|
| For the resolution .... .... .... | 4,478,000 |
| Against .... .... .... .... | 77,000 |
| Majority for .... .... .... | 4,401,000 |

---

At the sitting on Thursday, the 11th inst, when a resolution was put forward by Mr. E. Bevin (Dockers) stating that :—

"This Congress is of opinion that the time has arrived when the Government should assume control of the whole of the banking of the country, and calls upon the Parliamentary Committee to press this claim upon the Government at the earliest possible date."

Mr. Brownlie supported the resolution, and in the course of his remarks stated that United States engineers are paid 80 cents an hour, which at the present rate of exchange is about 3*s.* 8*d.* an hour, whereas the hourly rate paid here to the same class of workmen is less than 1*s.* 8*d.* an hour, including war wages and bonuses. The most recent available figures for the national income of the United States, those for 1914, show that the wealth produced was 72*l.* per head of the population, whereas the wealth produced in this country for the same period was only 50*l.* per head.

The resolution was carried unanimously.

A resolution was also passed stating that a policy of aggression against non-unionists was the only effective policy to follow if the burdens and benefits of an organised fight for better conditions were to be equitably shared. It also stated that all affiliated unions should make a determined effort to bring all non-members into their respective unions.

The greater part of Thursday's sitting was taken up in the discussion of a resolution to the following effect on direct action, put forward in the course of an able speech by Mr. T. Shaw, M.P. (Textile Workers) :—

"That this Congress declares against the principle of industrial action in purely political matters."

It was seconded by Mr. A. Hayday, M.P. (General Workers), whilst Mr. J. H. Thomas, M.P. (Railwaymen) and Mr. F. Hodges (Miners' Federation) spoke against it.

On the president putting a motion that the resolution be not further discussed nor voted on there voted :—

| | |
|---|---|
| For .... .... .... .... | 2,255,000 |
| Against .... .... .... .... | 2,086,000 |
| Majority .... .... .... | 169,000 |

---

At the sitting of the Congress on Friday last, the 12th inst., the questions dealt with were mostly of a political nature and outside our province. We may, however, put on record that a resolution proposed by Mr. J. H. Thomas, M.P., asking the Congress to instruct the Parliamentary Committee to demand of the Government the repeal of the Conscription Acts and the immediate withdrawal of British troops from Russia, failing this, asking that a special Trade Union Congress be called immediately to decide what action shall be taken, was carried with only two dissentients.

---

The Congress concluded its sittings last Saturday, when political questions were again mostly dealt with. After the Congress rose, a meeting was held of the new Parliamentary Committee, when Mr. J. H. Thomas, M.P., general secretary of the National Union of Railwaymen, and Labour Member for Derby, was unanimously elected chairman.

---

According to a report of the State Industrial Commission, factory wages in the State of New York have risen 77 per cent. in the last five years, namely, from an average of 12·70 dols. to 22·51 dols.

Factory workers in June earned 22·51 dols. on the average, whilst employees of water, light and power companies made 26·53 dols. Textile workers earned the least of all, 17·89 dols.

The following figures of the average weekly earnings of various industrial groups are of interest :—

| | Dollars. |
|---|---|
| Water, light and power .... .... | 26·00 |
| Paper manufacture .... .... .... | 25·84 |
| Metals and machinery .... .... | 25·16 |
| Stone, clay and glass .... .... | 24·19 |
| Printing and paper goods .... .... | 23·71 |
| Chemicals, oils and paints .... .... | 22·44 |
| Furs, leather and rubber .... .... | 22·16 |
| Food, liquor and tobacco .... .... | 21·25 |
| Wood manufactures .... .... | 20·75 |
| Clothing .... .... .... .... | 20·75 |
| Textiles .... .... .... .... | 17·89 |

The report is based upon figures received by the Bureau of Statistics from 1,648 firms and corporations employing 550,000 persons. In some cases wage increases were obtained by strikes; in other cases they were given voluntarily. A considerable number of employers reported a decrease in the number of hours.

The total of wages paid in all the manufacturing industries of the State in June of this year is nearly double the amount paid several years ago; but the bulk of wages paid can no longer be taken as an index of the expansion of business, because of the great increase both in prices and in wages. The number of people employed now gives a better measure of business conditions.

## H.M.S. "HERMES."

WE illustrate on page 380 a remarkable vessel which was launched from Sir W. G. Armstrong, Whitworth and Co.'s Naval Yard at Walker-on-Tyne on Thursday, September 11. The launch was performed by Mrs. William Cooper, daughter of the First Lord of the Admiralty, and the ship was christened the Hermes as she left the ways. The Hermes is the first ship for our Navy designed from the outset for the carrying of seaplanes and aeroplanes, although during the war several ships were adapted for this end. The keel was laid in January, 1918, and her principal dimensions are:—Length overall, 558 ft. 6 in.; length between perpendiculars, 548 ft.; breadth below water, 70 ft.; mean draught of water, 18 ft.; displacement about 10,400 tons; launching weight of the vessel about 6,400 tons. The propelling machinery consists of twin-screw geared turbines capable of developing 40,000 shaft horse-power, and her speed will be 25 knots per hour. The principal armament will consist of ten 6-in. guns, four 4-in. high angle guns, and four 3-pounder saluting guns, while her complement will be about 670 officers and men.

The hull, it will be seen from our engraving, presents some peculiarities, noticeably the straight stem and the wide flare at the bows, adopted, as in all the recent high-speed vessels, to ensure as dry a deck as possible for the seaplanes carried. The "blisters," which render the craft to a large extent immune from torpedo attack, are clearly visible in our engraving. The vessel, as stated, is the first of her type, and in present conditions is likely to be the last for some little time to come, as it is very essential that our ship-building plants should be developed in the immediate future to construction for the Mercantile Marine. In this connection it is of interest to note that 10 minutes after the launch of the Hermes the first plates of a new Cunarder were laid in the same berth.

## WIRELESS NAVIGATION FOR AIRCRAFT.*

By J. ROBINSON, Capt., R.A.F.

1. THE ordinary methods of navigation which are used for ships at sea are not sufficient for aircraft, as the conditions as regards drift are of an entirely different order. It is thus necessary to use some other means for determining position in the air. Drift is of a very large magnitude in the air, and by night or in fogs it is very often impossible to apply dead reckoning methods. The use of wireless bearings is the most hopeful method of progress, as bearings can be obtained with considerable accuracy.

The systems for determining bearings that were known at the beginning of the war were:—

(a) *The Single Coil Method.*—When such a coil is rotated about a vertical axis, the intensity of the wireless signal varies from zero to maximum, being zero when the plane of the coil is at right angles to the direction of the incoming waves.

(b) *The Bellini Tosi System.*—This system uses two fixed loop aerials at right angles to each other, the moving part being a small coil rotating between two coils at right angles which are in the circuits of the two fixed aerials.

(c) The Tele-Funken Clock.

(2) There are two distinct methods of employing wireless bearings in order to determine position:—

(a) By the first method the machine transmits and the direction-finding stations are on the ground. Each direction-finding station finds the bearing on the moving object and communicates its bearing to a central station. There the position of the moving object is worked out from the various bearings and re-transmitted to it.

(b) By the second method the moving object, either aircraft or ship, has its own direction-finding apparatus and finds bearings on fixed transmitting stations.

As regards aircraft, method (a) was used largely by the Germans. This method has considerable drawbacks, the first being that, in case of war, when the aircraft transmits to ask for its position, this is also disclosed to the enemy.

Secondly, only very few aircraft can be dealt with, as a considerable amount of transmission is required for a single aircraft to find its position. In consequence it was decided to attempt to use method (b) in the British air service.

3. *Royal Air Force System.*—In attempting to apply direction-finding systems to aircraft it was found that considerable modifications to the known systems had to be applied. The single coil and Bellini Tosi systems are what are called minimum systems, i.e., in order to determine the bearing one finds the minimum by swinging the coil through this position until the signal is heard on both sides. On aircraft, as there is considerable extraneous noise, the region of this minimum is widened, and, in consequence, accuracy of the system diminishes. It is necessary to use a system where signals can be heard whilst the bearing is taken. The system devised is to use two coils at right angles, which can be rotated together on a vertical axis. One coil alone is used first and the system rotated to be somewhere near the maximum of this single coil. Then the second coil is introduced and its effects added to or subtracted from those of the first coil. If the first coil is correctly on its maximum then the second coil will be on its minimum, and thus there is no change of intensity on adding or subtracting the effects of this coil by a reversing switch. This method enables bearings to be taken whilst the signal is heard, and it is easy to see that it can be applied to any system which has hitherto been a minimum system. Having devised this system, there were other problems to be solved.

(a) One was to obtain efficient strength of signals. It was uncertain as to whether loops could be obtained of sufficient size to give loud enough signals to hear over the noise of the engine.

(b) The Bellini Tosi system was considered to be too complicated, as at that time it was necessary to tune the two aerials to exactly the same frequency, and unless this system is very carefully installed fairly large errors are introduced.

4. It was hence decided to use the rotating aerial system. This was done in two ways:—

(a) *The Wing Coil System.*—In this case the aerials are fixed rigidly to the aeroplane, which has to be rotated in order to determine the bearing. This system is particularly useful in the case of flying towards an objective where there is a wireless station. One particular example is where a wireless station exists at the aerodrome and the machine can thus return home by merely heading to this wireless station.

(b) *The Rotating Coil System.*—In this case the rotating coils are placed in the fuselage and are rotated independently of the machine. This is particularly useful on the larger type of aeroplane, and enables position to be determined whenever a sufficient number of transmitting beacon stations can be heard.

5. Considerable difficulties had to be overcome to bring the R.A.F. system to a stage of perfection:—

(a) The extraneous noises on an aeroplane are considerable, but besides there is a far greater disturbing influence in the electrical disturbance due to the magneto. This produces considerable noise in the telephones and cannot be overcome by amplification of signal strength. It is necessary to cut out this electrical disturbance. The cause of this disturbance was traced to the emission of very short waves by the magneto, the wave length being of the order of from 5 m. to 30 m. It is possible to use short wave stoppers to cut out these waves, but by far the most efficient method of eliminating this disturbance is to screen the whole magneto system.

(b) When using the fuselage coil system it was found that corrections had to be applied for the deviation produced by the metal work of the aircraft. These corrections can be determined by swinging the aircraft in a similar way to the swinging of a ship to adjust the compass.

6. In addition to the preceding difficulties, there is another trouble in the variation of bearings produced by atmospheric influence. The extent of these variations is not large, possibly never more than about 3 deg. when using waves of 2,000 m. and upwards. The problem of this variation is one that should be investigated at an early date. The R.A.F. system of D.F. gives means for recording these variations very accurately. The sensitiveness of this system is under control, and depends on the ratio of the area turns of the two coils. It is possible to design coils so that the system is sensitive to $\frac{1}{4}$ deg. This is the case when the minimum coil has its area turns about eight times those of the maximum coil. With such a system it is easy to conceive an automatic arrangement so that the variations in bearings can be automatically recorded.

7. Excellent results have been obtained with the R.A.F. system of wireless navigation. A large number of flights have been made, and it has been found that the mean error of bearing is $1\frac{1}{2}$ deg., when using beacon stations whose distance varies from 20 to 500 miles. Under these circumstances when three beacon stations are available the mean error in determination of position was found to be 7 miles.

Flights have been made purely by wireless navigation. One particular flight was made from Biggin Hill to Paris and back from Paris to Brighton. In both of these flights the machine was above the clouds most of the time. Position was determined by wireless bearings, and the course was set or altered from these determinations. The navigator was in a position so that he could not look out of the aeroplane, and he was able to determine the force and direction of the wind and to forecast the time of arrival at his destination within two minutes.

* Paper read before Section "G" of the British Association at Bournemouth.

EDUCATIONAL GRANTS FOR EX-SERVICE MEN.—Under the Government scheme of financial assistance for the higher education of ex-service officers and men, the total number of grants awarded by the Board of Education now amounts to 9,500, including 4,000 officers and 5,500 men. The courses in respect of which grants have been awarded include more than 2,500 for engineering and technological subjects, between 800 and 900 for classics, philosophy and literature, and about 1,200 for pure science and mathematics. Applications are still being received in large numbers and are being dealt with at the rate of more than 100 a day.

UNITED STATES GOVERNMENT ARMOUR PLANT.—We read in *The Iron Age* that the United States Government requires the services of a superintendent of forge shops and of a superintendent of melting shops, at 5,000 dols. a year, in the new Naval Ordnance Plant, South Charleston, W. Va. Other positions open in these works are: Foreman of heat treatment on large guns, 8 dols. to 12·56 dols. a day; foreman of 14,000-ton presses for armour plate and guns, 11·84 dols. to 13·28 dols. a day; foreman of small guns, 8 dols. a day; and foreman of heat treatment of projectiles, 8 dols. a day. Candidates for these positions are to apply to the Civil Service Commission, Washington, D.C.

## NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

*Iron and Steel.*—Two factors have interfered with progress during the past week, reducing the output considerably at a time when manufacturers are seeking to respond to the national call. The Doncaster races always take a large number of men from the South Yorkshire staple trades. This year it is believed that a record number went, and those that were left did not show any marked inclination towards extra effort in their fellow employees' absence. But industry in the Sheffield and Rotherham districts has been most seriously hit by the tramway strike in both places. Large numbers of men live beyond a reasonable walking distance of the various works, and the unexpected stoppage of the tram service on Thursday largely disorganised industry. Engineering employers have sought to minimise the difficulty by organising a rough-and-ready service of works lorries, steam wagons, &c., to and from the manufacturing areas, but the number of vehicles available is sufficient to meet only a small portion of requirements. Unfortunately there is no prospect of an immediate settlement of the dispute, and until that is brought about industry will suffer more or less seriously. The corporations realise the loss that is resulting, and are using every influence to convert the strikers to a reasonable frame of mind. Failing this, other men may be enrolled in the strikers' places, and a restricted service instituted. Raw material prices remain largely at last week's level, with the exception of fractional advances in basic iron, the call for which cannot be met from local output. Forge iron is rather more plentiful, but the scarcity of finished iron is inevitably directing consumers' attention to the advantages of offers from outside sources. Some American material is coming to hand, and there are indications that trade will be resumed before long with Belgian bar makers. The latter's quotations, for local delivery, work out at about 15*s.* per ton less than the South Yorkshire official price. Normal working conditions have again been restored at mills, forges and iron works. Export trade shows several welcome improvements. Finished steel is attracting more attention from overseas buyers, and there is increased activity in wire manufactures and heavy steel plates. One of the most satisfactory features is the larger number of bookings for railway wheels, axles and tyres. India, which before the war drew largely on the South Yorkshire output, is again becoming a substantial buyer. Improvement in crucible steel is slow, but owing to the increased number of furnaces at work a proportionately large amount of business is required to produce an appearance of equal activity. The demand for the best qualities of tool steel is only moderate. Irregular conditions obtain in regard to open-hearth steel. The quantity available for export is said to be deficient, but at the same time furnaces in the Sheffield district are not working anything like full time, and output is restricted. A healthy demand continues for files both for home and foreign use. Otherwise conditions are slightly easier in the tool departments.

*South Yorkshire Coal Trade.*—Owing to the increasing pressure on contract supplies, the tonnage on offer in the open market is very small. Best steam hards are in active request by home consumers of all classes. Railway companies are making special efforts to build up their depleted reserves. Blast furnaces are also pressing for supplies, and there is a fair demand for export. Cobbles and nuts are firmly held at maximum prices. Slacks have recovered their recent temporary weakness. In the house coal section there is a general pressure from all quarters. Outputs are easily absorbed. Cokes are scarce. Quotations:—Best branch handpicked, 33*s.* to 34*s.*; Barnsley best Silkstone, 33*s.* to 33*s.* 6*d.*; Derbyshire best brights, 31*s.* to 32*s.*; Derbyshire house coal, 28*s.* 6*d.* to 29*s.*; Derbyshire best large nuts, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire smalls, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* to 25*s.* 6*d.*; nutty slacks, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*The Cleveland Iron Trade.*—There is a quiet feeling in Cleveland pig-iron. Certainly Continental inquiry for the better kinds is still heavy, but business is difficult to arrange owing to irritating export regulations. Permits to ship abroad are as difficult as ever to secure, notwithstanding that home consumers are not buying, as they have arranged contracts to cover their needs as far ahead as they care to commit themselves. Whilst foundry pig-iron can still hardly be purchased for prompt delivery, there are signs that there may be fair quantities available for disposal in the near future. Forge iron is selling better, but this quality continues abundant. For home consumption, No. 3 g.m.b. and No. 4 foundry are 160*s.*, No. 1 is 164*s.*, and No. 4 forge ranges from 157*s.* to 160*s.*; whilst for export rates are 5*s.* above the foregoing quotations.

*Coke.*—Coke continues pronouncedly scarce, though the shortage is slightly less acute than it has been. Local consumers are much harrassed by the inadequate supply, and are pressing insistently for deliveries. Average blast-furnace kind is 48*s.* at the ovens, and low phosphorus sort is 49*s.* 6*d.* at the ovens. For export patent oven coke is 90*s.* to 95*s.*, and gas-house product 95*s.* to 100*s.*

*Hematite Iron.*—There is now an ample supply of East Coast hematite. Home and foreign demand are not extensive, but the latter may shortly improve, as the comparatively cheap iron purchased by Italy a

little while ago has now been seen well into, and that country may be in the market to buy again in the next few weeks. Rate of exchange, however, threatens to hamper business with Italy. Export licences are still granted sparingly in this branch also. Nos. 1, 2 and 3 are quoted 200*s.* for home use and 205*s.* for export, and No. 1 is 202*s.* 6*d.* for home purposes and 207*s.* 6*d.* for shipment abroad.

*Foreign Ore.*—Very little new is ascertainable concerning foreign ore. Business is almost at a standstill, consumers continuing to hold off the market. Most of them are carrying considerable stocks and have good orders booked, but deliveries are now falling off. September imports promise to be no more than half of the August unloadings. Tonnage is less plentiful, and freights are inclined to stiffen, but as yet steamers can still be fixed at 25*s.* Bilbao-Middlesbrough. Rubio ore, of 50 per cent. quality, is in the neighbourhood of 53*s.* 6*d.* c.i.f. Tees.

*Manufactured Iron and Steel.*—There is not much new to report with regard to finished iron and steel. Rail producers have a good deal of work on hand, and plate manufacturers have specifications on hand sufficient to keep the mills busily employed, but new contracts, of any moment, are not coming forward except in the sheet department. There is active inquiry for sheets, and further substantial sales are reported. Export prices are still matter of negotiation, and may be given as a little above the following rates, which are among the principal quotations to home customers:—Common iron bars, 22*l.*; marked bars, 25*l.*; strip iron, 23*l.* 5*s.*; steel ship, bridge and tank plates, 18*l.* 5*s.*; steel boiler plates, 21*l.* 10*s.*; steel angles, 17*l.* 15*s.*; steel joists, 17*l.* 10*s.*; black sheets, 24*l.*; galvanised sheets, 30*l.*; and heavy sections of steel rails, 16*l.* 10*s.*

## NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

*The Local Markets.*—Generally the coal market is firm and the improvement reported last week has been maintained. The recent increase in outputs has not been maintained, for in the week ending Saturday last it totalled 934,492 tons, which is 15,888 tons and 41,460 tons less, respectively, than in the preceding two weeks. A large proportion of production has been allocated to home consumption, and for shipment coastwise as bunkers, 23 vessels having been directed from the foreign trade to United Kingdom ports during the past week-end. Collieries have also received instructions to send extra quantities to railways in view of unsatisfactory stocks. The export trade as usual has been adversely affected, and shippers have not been able to secure supplies so freely as was the case a week ago. In the week ending September 6 foreign shipments totalled 337,709 tons from the South Wales ports, which is roughly 6,000 tons less than in the preceding week, and of this 203,859 tons went to France and French Possessions. The supply of shipping in port is ample to meet exporters' current requirements; loading accommodation is at a premium, and there are a number of vessels waiting to go under the tips. Collieries, too, are on the whole fully stemmed and have little coal for disposal, and are consequently in a position to hold for top prices, though in isolated cases a buyer with a boat under the tips could secure moderate concessions for spot delivery. Current prices are on the basis of 85*s.* for Admiralty large, 82*s.* 6*d.* for Monmouthshire large, and best dry large, with the cheaper qualities from 75*s.* Smalls, too, are tight, especially the best descriptions, for which 65*s.* is commanded, with ordinaries at 55*s.* and inferiors from 40*s.* Prices for bituminous sorts are steady on the basis of 72*s.* 6*d.* for No. 2 Rhondda large and 65*s.* for throughs. Coke is firm and scarce round 105*s.* Coke makers have fixed the minimum price for inland consumption from now on till the end of the year at 52*s.* 6*d.* per ton for blast furnaces, and 65*s.* 6*d.* for other purposes. Patent fuel is irregular. Some makers are well situated and demand up to 85*s.*, but others not so comfortably placed are offering supplies at from 77*s.* 6*d.* Pitwood remains plentiful with the inquiry poor and prices from 55*s.*

*Times Shipping Company, Limited.*—Mr. Frank Shearman, managing director of the Mountstuart Dry Docks, Limited, John Shearman and Co., Cardiff, and Mordey, Carney and Co., Newport, and Mr. Palin Evans, shipowner, have acquired a controlling interest in Messrs. Peacock, Davies and Parker, managers of the Times Shipping Company, Limited, which owns four steamers of about 21,000 tons deadweight. Mr. Shearman and Mr. Evans have acquired the interests of Mr. J. H. Peacock, chairman of the company, Mr. Rupert Glossop and Mr. William Thomas. Mr. Frank Shearman becomes chairman of the company and Mr. Evans will take an active part in the management.

*A 5,000,000l. Deal.*—Mr. H. S. Berry, acting in conjunction with Mr. D. E. Llewellyn, and Viscountess Rhondda, have acquired the control of John Lysaght, Limited, manufacturers of sheet, iron and steel. The transaction is a record for South Wales and involves a sum close on 5,000,000*l.* sterling. The capital of Lysaghts amount to 1,000,000*l.* Under the new control the Board will be reconstituted with Mr. H. S. Berry, chairman, and Mr. D. R. Llewellyn, deputy chairman.

## NOTES FROM THE NORTH.

GLASGOW, Wednesday.

*Scotch Steel Trade.*—Steelmakers in the West of Scotland have now got into full swing once more, and are as actively employed as it is possible for them to be under existing circumstances, the bulk of the output being material required by the Clyde shipbuilders, ship and boiler plates especially being a very heavy item. In consequence, the plate mills are having a particularly strenuous running, which, it is expected, will stretch some distance ahead. The general expansion of trade goes on apace, but mainly on home account, the various difficulties which stand in the way of a good export trade being, at the moment, well nigh insurmountable. For one thing, the high rates presently in operation are a deterrent force, besides which, transport is still a problem which time alone can solve. Certainly, with the construction of naval shipping no longer a matter of vital importance to the nation, shipbuilders are now in a position to devote all their energies to the construction of mercantile vessels of all descriptions, and this in two separate and distinct forms will help to develop the steel industry. Makers in the district seem to have little apprehension regarding foreign competition, the local opinion being that once all is well in train there should be no difficulty in us holding our own. There is a steady demand for sectional material of every kind, and the mills are fully employed. In several instances makers have had to close their order books to facilitate the delivery of the work in hand.

*Malleable Iron Trade.*—Business in the malleable iron trade runs on as brisk lines as at any period during the war, and as is usual at this season of the year, the demand for agricultural sections is almost sufficient to keep the mills going without any other work at all. Bars for rivets and horseshoes are also so greatly in request that there is little danger of any scarcity of work for some considerable time to come. With so heavy a demand on their resources for home consumption makers cannot be induced to ship any material abroad except for some very special order—it really all goes by favour, even at the present enhanced values. The activity is as marked in the steel as in the iron departments, and as each order is completed there are two to take its place.

*Scotch Pig-Iron Trade.*—From the evidence to hand it is quite apparent that the pig-iron trade is on the eve of the wished-for development as everything points to a decided opening-out, although there is not much new business as yet. The increasing activity in the shipbuilding yards makes for more work in the steel-making industry, and this again reacts on the pig-iron trade. Hematite in particular, the tonnage of which is very heavy, passes direct to the steelmakers, who are constantly clamouring for further supplies. Practically none of the output is as yet available for export. Both forge and foundry iron are now more easily obtainable. Transport is still rather a difficult problem, but every endeavour is being made to place matters on a more satisfactory footing.

FINLAND'S POTENTIAL WATER POWER.—Out of a total estimated water power of 3,000,000 h.p. at average water-level, specialists consider about 1,050,000 h.p. to be of direct use for industry, says *The Bulletin of the Federation of British Industries*. Of this, only 15,000 h.p. is at present utilised, thus leaving considerable possibilities of development. Of the 79 waterfalls in Finland with potential capacities of horse-powers from 5,000 to 300,000, 42 range from 5,000 h.p. to 20,000 h.p., 25 from 20,000 h.p. to 50,000 h.p., 6 from 50,000 h.p. to 100,000 h.p., and 6 from 100,000 h.p. to 300,000 h.p.

RESEARCH ASSOCIATIONS.—The Glass Research Association, established in accordance with the Government's scheme for encouraging industrial research, has been licensed by the Board of Trade as a company not trading for profit. The secretary is Mr. E. Meigh, 7, Seamore Place, W. 1. The Department of Scientific and Industrial Research have approved the Memorandum and Articles of the British Refractories Research Association, which are now under consideration by the Board of Trade. Mr. A. C. Rann, 14, Great George-street, Westminster, S.W. 1, will act as secretary of the association.

PROPOSED "MADE IN U.S.A." TRADE MARK.—*The Board of Trade Journal* reports that the Merchants' Association of New York has sent to members of Congress and other Federal officials a brief in opposition to the Bill which authorises the adoption, registration and protection of a national trade mark to distinguish merchandise produced in the United States. The memorandum claims that the Bill will not bring about the results which it aims to produce, and that its operation will injure, instead of promoting, trade with foreign nations. Although the general use of a suitable legend showing the origin of merchandise, such as "Made in U.S.A.," accompanied by a suitable emblem, is favoured by the association, the memorandum dwells on the legal obstacles which will be encountered. The chief is the practical difficulty of determining and enforcing the standards to be followed in licensing or refusing to license houses to use the trade mark. Again, objections are raised to the granting of too much responsibility and authority to one man—the Secretary of Commerce—in enforcing the provisions of the Act. It is stated that the power which the Act would give to the Secretary of Commerce is dangerous, inasmuch as it would give him complete control over the business of persons engaged in foreign trade. He would also encounter difficulties in fixing and enforcing standards based upon the grades and accepted traditions of manufacturers and trade associations in the United States by the necessity of interpreting and considering at the same time the standards of a large number of foreign countries in each of which the standards and traditions vary. The attempt to establish and enforce standards, therefore, would be sure to injure American sellers or offend foreign powers.

## NOTICES OF MEETINGS.

THE INSTITUTE OF METALS.—The Autumn Meeting will be held in Sheffield on Wednesday and Thursday, September 24 and 25. Wednesday, 24: 9 a.m. to 10 a.m., Inspection of the University of Sheffield (and during the day); 10 a.m., General Meeting of members in the Mappin Hall of the University, St. George's-square, when the Vice-Chancellor will welcome the members—A selection of communications will be read and discussed; 12.45 p.m., The meeting will be adjourned to the following day; 1 p.m., the Master Cutler (Sir Albert Bingham) will entertain the members of the Institute and their ladies to lunch in the Cutlers' Hall, Church-street; 2 p.m. to 3.30 p.m., visit to the Master Cutlers' works (Messrs. Walker and Hall); 3.30 p.m. to 7 p.m., (a) motor excursion, (b) visits to works; 8 p.m. to 10 p.m., reception by the Lord Mayor of Sheffield in the Town Hall. Thursday, 25: 9 a.m. to 10 a.m., Inspection of the University (and during the day); 10 a.m., General Meeting of members in the University—a selection of communications will be read and discussed; 12.30 p.m., the meeting will be concluded; 1 p.m. to 2 p.m., lunch at certain Sheffield firms; 2 p.m. to 7 p.m., visits to works. The following is a list of the communications that are expected to be submitted: (1) Professor P. G. H. Boswell, O.B.E. (Liverpool), on "Moulding Sands for Non-Ferrous Foundry Work"; (2) Professor C. H. Desch, Ph.D. (Glasgow), Second Beilby Report on "The Solidification of Metals from the Liquid State"; (3) Miss H. E. Fry (Teddington) and Dr. W. Rosenhain, F.R.S., Vice-President (Teddington), on "Observations on a Typical Bearing Metal"; (4) Dr. W. H. Hatfield and Captain G. L. Thirkell, B.Sc. (Sheffield), on "Season Cracking of Brass"; (5) Dr. Zay Jeffries (Cleveland, Ohio, U.S.A.), Note on "The Micro-Mechanism of the Aging of Duralumin"; (6) Mr. R. E. Leader, B.A. (Sheffield), on "The Early History of Electro-Silver Plating"; (7) Mr. E. A. Smith and Mr. H. Turner (Sheffield), on "The Properties of Standard or Sterling Silver, with Notes on its Manufacture"; (8) Dr. J. E. Stead, F.R.S. (Middlesbrough), on "The Ternary Alloys of Tin—Antimony—Arsenic"; (9) Dr. F. C. Thompson, B.Sc. (Sheffield), Note on "Graphite and Oxide Inclusions in Nickel Silver"; (10) Dr. F. C. Thompson, B.Sc., and Mr. F. Orme, M.Met. (Sheffield), on "Some Notes on the Constitution and Metallurgy of Britannia Metal."

THE ASSOCIATION OF DROP-FORGERS AND STAMPERS.—Wednesday, September 24, at 7.30 p.m., in the Assembly Hall, Chamber of Commerce, New-street, Birmingham, a lecture will be delivered by Mr. J. Fearn, A.M.I.M.E., on "The Effect of Indirect Charges on Costs."

THE ASSOCIATION OF RAILWAY COMPANIES' SIGNAL SUPERINTENDENTS AND SIGNAL ENGINEERS.—Thursday, September 25, the Fifty-ninth Conference will be held at the Railway Clearing House, London.

INDUSTRIAL PROBLEMS.—Through the courtesy of the Corporation of London, a series of fortnightly lectures on Industrial Problems will be delivered at the Guildhall, at 4.30 p.m., commencing on October 7. The speakers will include Mr. E. J. P. Benn, Professor Ripper, D.Sc., C.H., Dr. Russell Wells, the Right Hon. Sir Auckland Geddes, M.P., Sir George Paish and the Right Hon. Lord Emmott, G.C.M.G., G.B.E. Tickets for this series can be had on application to the Secretary, Industrial League and Council, 66, Victoria-street, S.W. 1.

QUEENSLAND GOVERNMENT'S STATE MINING PURCHASE AT CHILLAGOE.—The taking over of the Chillagoe Company's enterprises in North Queensland has now been completed, the Government having come into possession in June last. The manager who was appointed by the Government some time ago has been engaged in preparing the smelters and other machinery in readiness to commence smelting operations. A good deal of raw ore is in readiness, but alterations to the bins and other appurtenances have been in progress. The mines will be producing not only copper, but lead and silver as well, and it is considered likely that they will also furnish lime as a fertiliser for agricultural districts. Until the Chillagoe Company has coke ovens of its own, coke will be obtained from the south for working the smelters, but eventually it is hoped to obtain it from Mount Mulligan.

THE INDUSTRIAL LEAGUE AND COUNCIL.—The Industrial Reconstruction Council and the Industrial League, who are amalgamating under the new title of the Industrial League and Council, have arranged a series of fortnightly Conferences dealing with the working of Whitley Councils set up in the following industries: Road transport, silk, wool and allied textiles, pottery, building and gloves. The first of these conferences will take place on September 30, at 6 p.m., in the Hall of the Institute of Journalists, when Mr. G. A. Dutfield, J.P., and Mr. E. Bevin, J.P., representing respectively employers and workers in road transport, will give short addresses, the meeting will then be open to public discussion. Whitley Councils affect nearly 5,000,000 workers, and all who are interested in the movement are invited to attend. A similar series of conferences on scientific management will take place in the same hall on alternate Wednesdays at 5.30 p.m. The first of these commences on October 8, when addresses will be given by representatives from the managerial staff and workers of Messrs. A. Lloyd and Co., tin box and canister makers, Cheapside. Admission is free, and no cards are necessary.

# LAUNCH OF H.M.S. "HERMES."

CONSTRUCTED BY MESSRS. SIR W. G. ARMSTRONG, WHITWORTH AND CO., LIMITED, NEWCASTLE-ON-TYNE.

(*For Description, see Page* 378.)

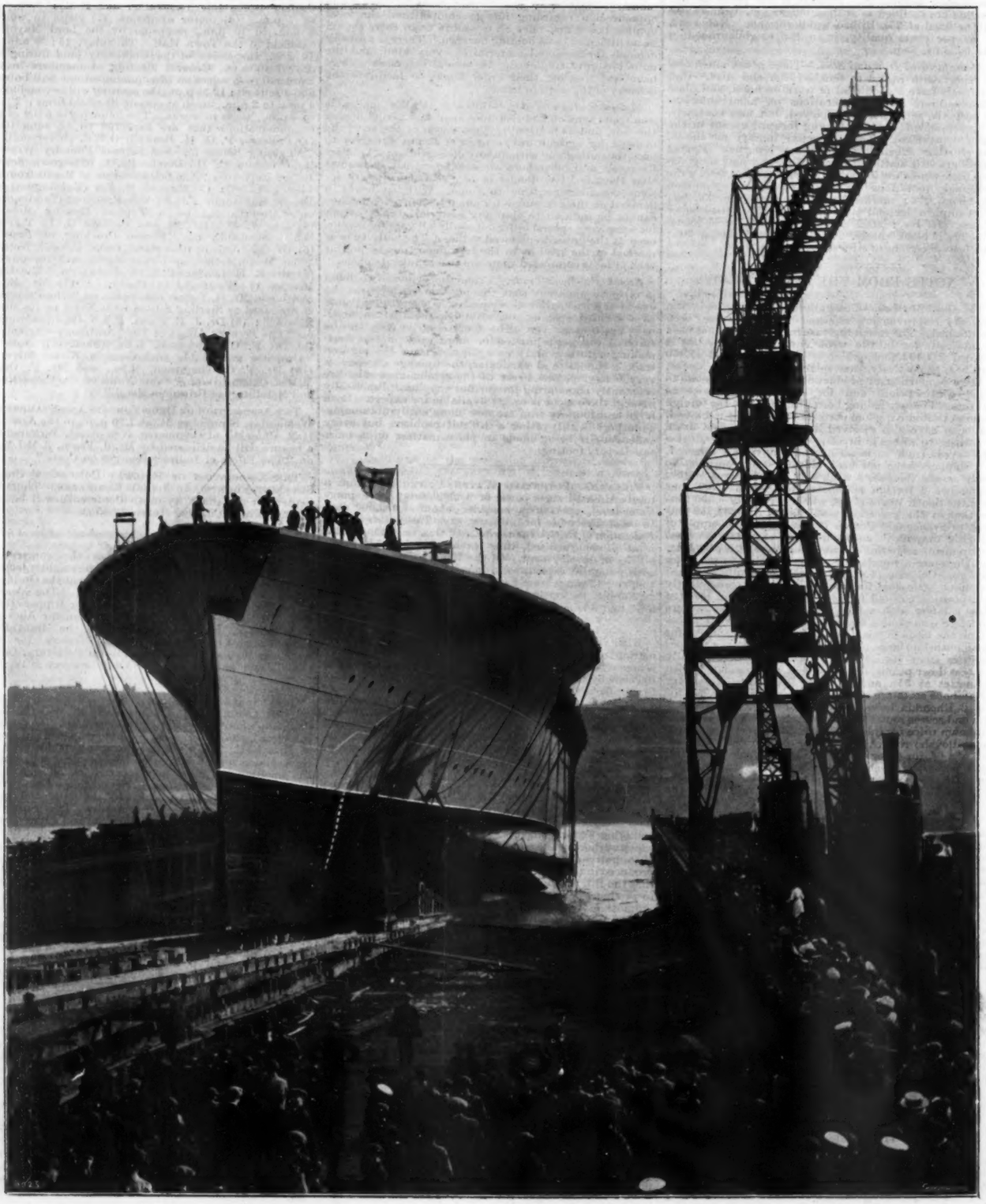

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*Fig.34.*

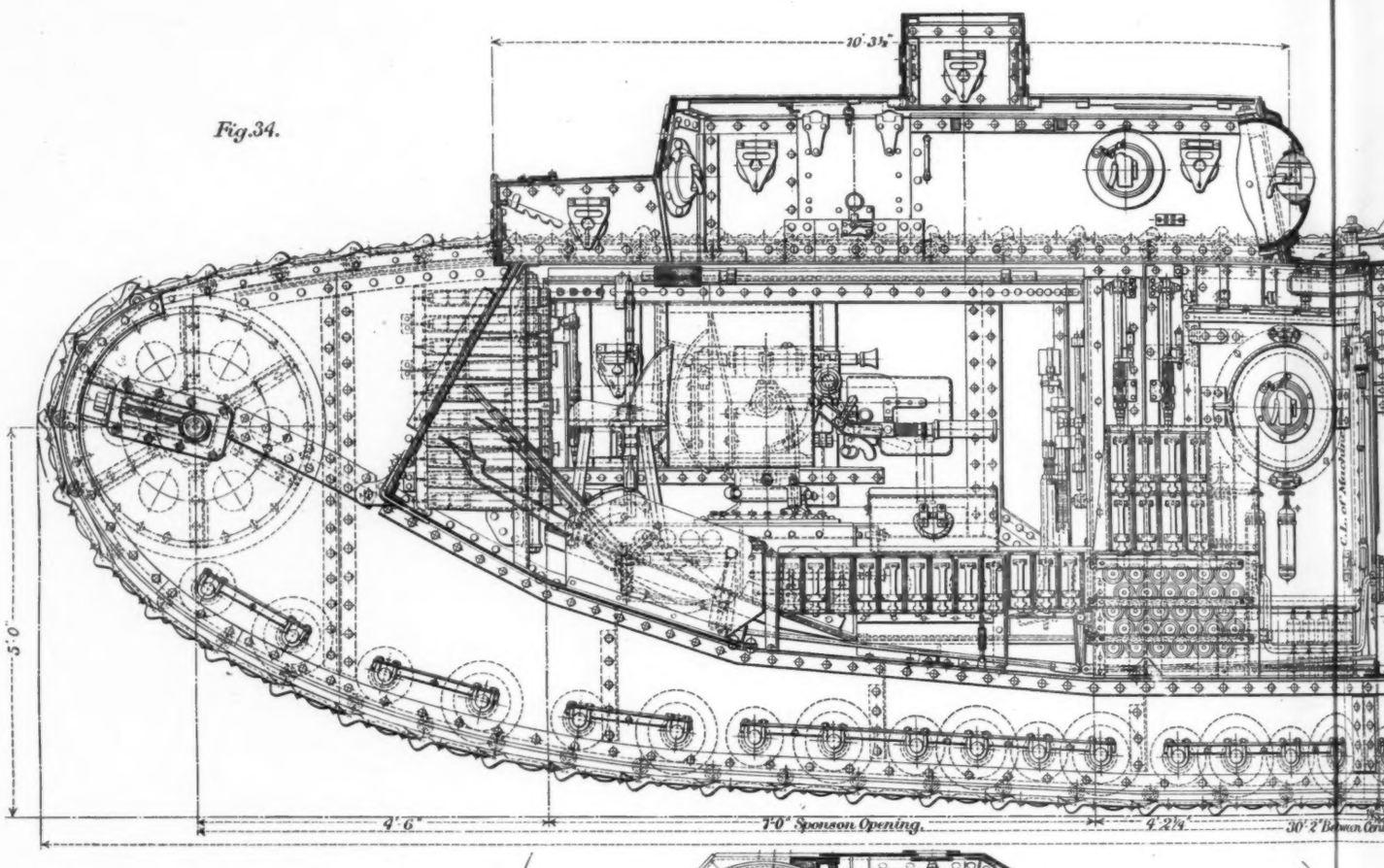
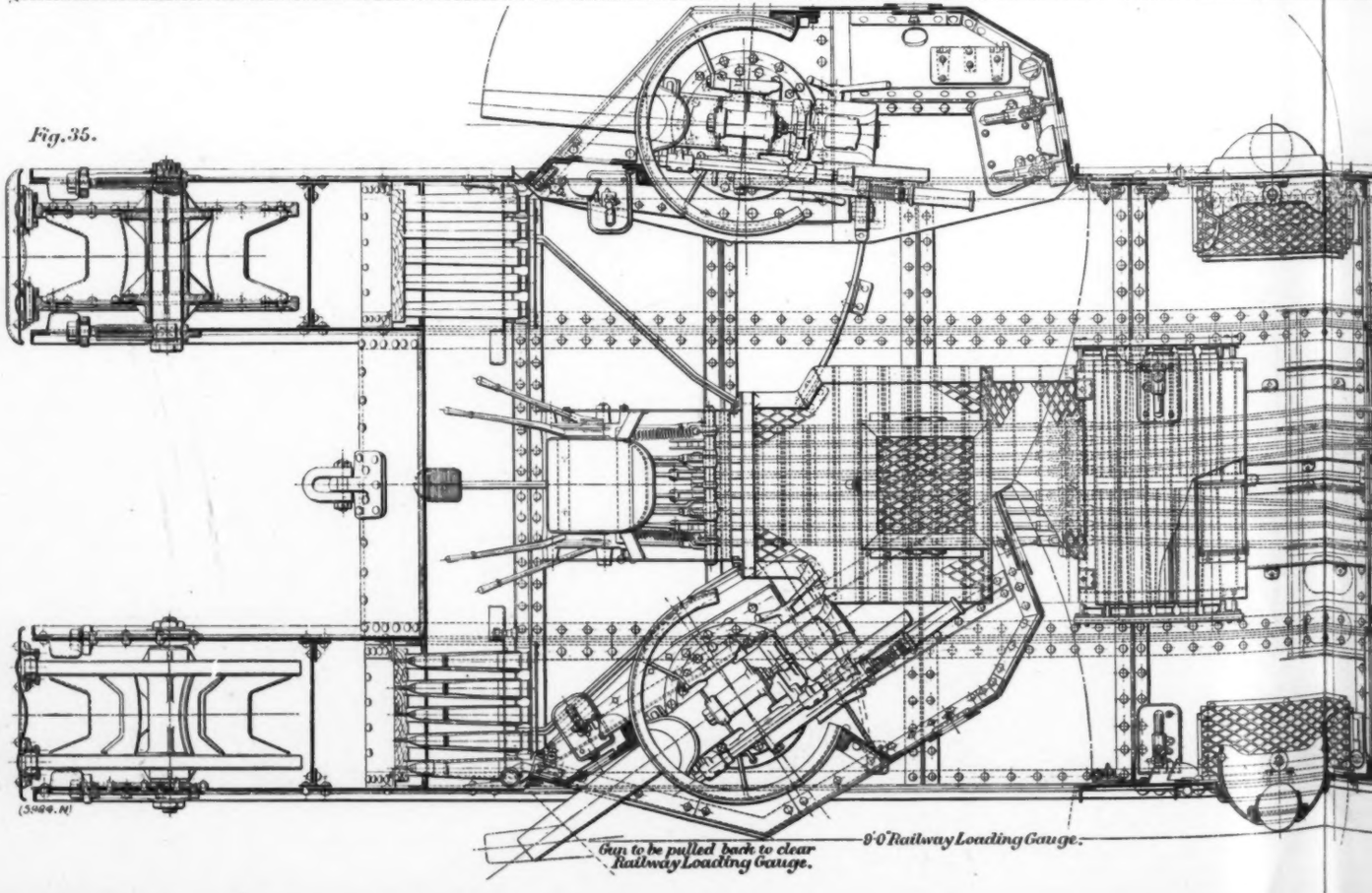



*Fig.35.*

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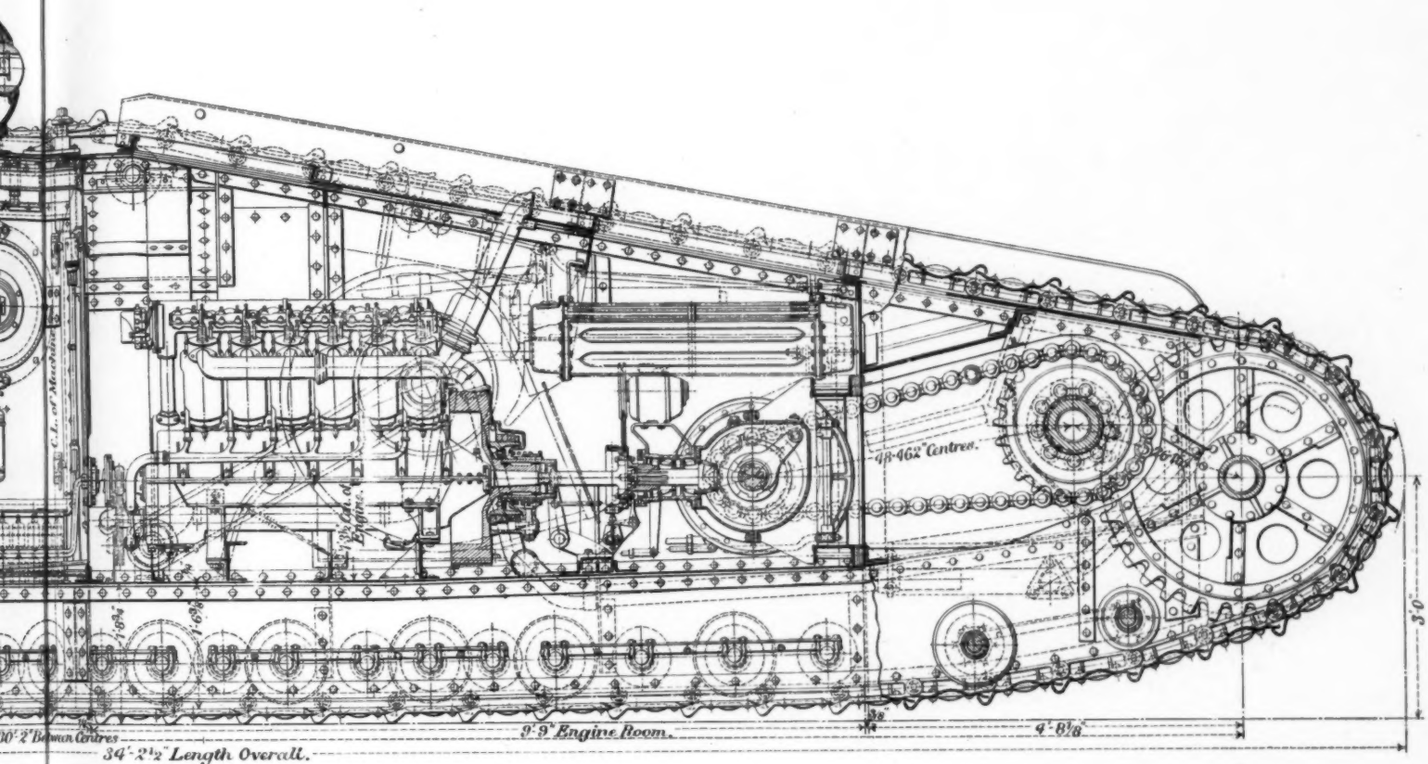
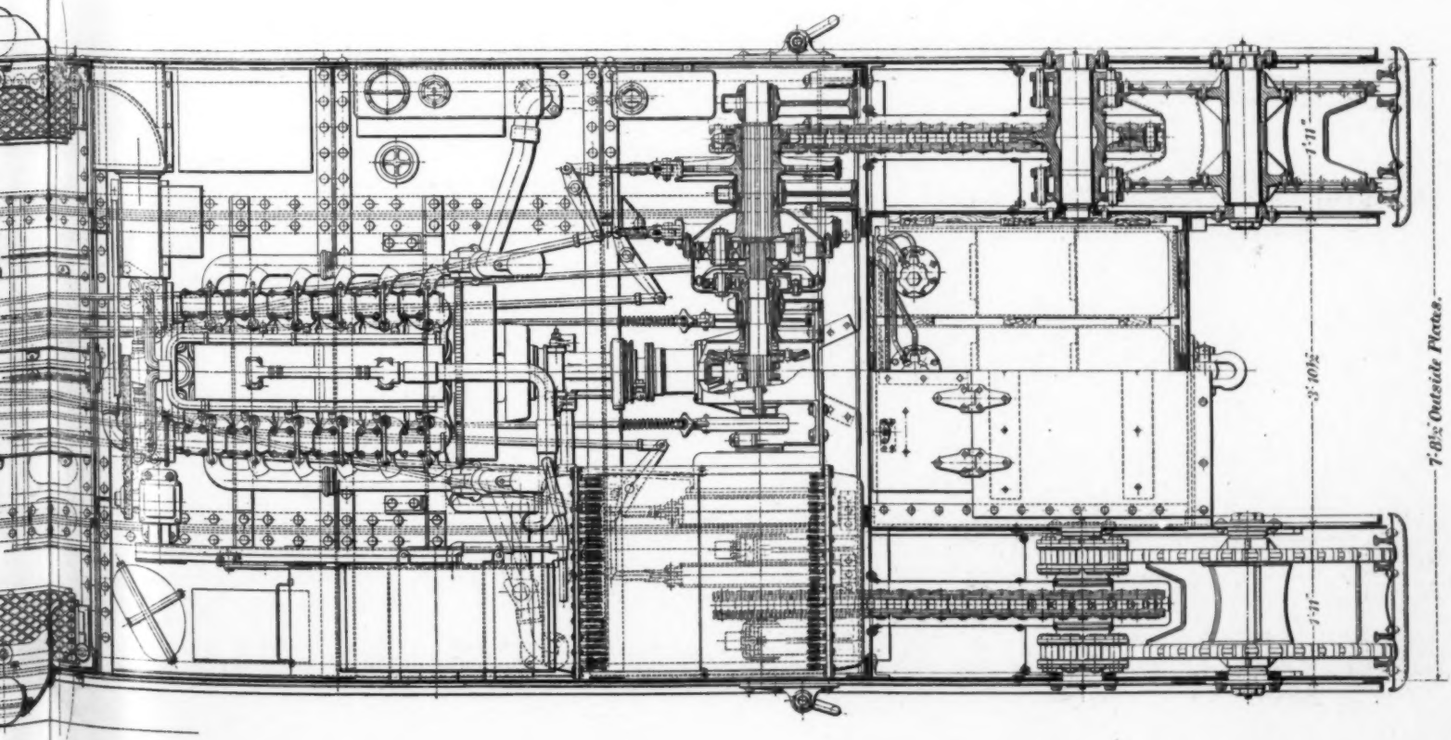
# SED IN THE WAR; MARK VIII.

(Description, see Page 371.)



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## ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

**Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication, and certainly not later than Monday morning.**

## SUBSCRIPTIONS, HOME AND FOREIGN.

### REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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**NOTICES OF MEETINGS.**

**Notices of Meetings to take place during the present and next week will be found on page 379.**



# ENGINEERING.

***FRIDAY, SEPTEMBER* 19, 1919.**


## INTERNAL COMBUSTION ENGINED WARSHIPS.

LORD FISHER'S recent communications to the *Times*, urging economy and suggesting characteristically sweeping means to that end, have raised afresh some controversial points. The nation is not unmindful of the contribution in the past of Lord Fisher in adopting strong measures to ensure at all costs that the efficiency of the Fleet should be maintained at the highest possible value. A reminder is hardly needed of the part played in securing such efficiency of fighting force by the water-tube boiler, the steam turbine, the big gun, and the submarine, or of our indebtedness to Lord Fisher in his advocacy of these important factors. As a result, such improvements were effected in naval engineering that when the war commenced we led the world by a good margin. Lord Fisher also realised at an early date the potentialities of the internal combustion engine as a means of propulsion for fighting ships.

This subject was first raised in a paper before the Institution of Naval Architects given by Sir James McKechnie on March 20, 1907. Later on, it will be remembered, a Royal Commission was set up at the instigation of Lord Fisher, and presided over by him. The findings of this Commission have not been made public, but it was generally recognised that the report was a disappointment to Lord Fisher to the extent that it indicated that at the time when the inquiry was held a great amount of development still remained to take place before the internal combustion engine could be regarded as assailing the first place in naval propulsion firmly and justly occupied by the steam turbine. The Commission certainly served a useful purpose by the collection of evidence and data which showed clearly the state of the internal combustion engine at that time and indicated the work to be undertaken and the problems to be solved before a reconsideration of the application of the Diesel engine to naval work of high power need arise. Oil having been proved in practice in the interval to be the fuel *par excellence* for naval use, and the Diesel being that type of internal combustion engine best suited to utilise that fuel with maximum economy at relatively high powers (for this class of prime mover) our present remarks may be confined solely thereto.

Lord Fisher's recent letters to the Press have given rise in the minds of many engineers to that reconsideration. During the war experiments on such subjects would not have been justified, and reliance was placed rather on combinations of well-tried units, changes being made only after full consideration of the maximum possible detrimental effect on fighting efficiency should the anticipated improvement be completely negatived. Such, however, was the mass of the production of naval machinery undertaken during the war that short steps carried us relatively long distances, and in effect the progress made during this period in most of the branches of naval engineering was greater than in any previous period of time of equal length. The one exception is undoubtedly the Diesel engine. The same 100 brake horse-power per cylinder that was standard in our submarines before the war was the standard, except for minor improvements, at the end. The Germans in their submarines had engines of some 300 brake horse-power per cylinder (see ENGINEERING, "German Submarine Diesel Engines," June 13 last, page 763), and the Clyde during the war produced a merchantman with two main engines of 16 Diesel cylinders, developing in normal running at sea a total of 6,600 indicated horse-power, or over 330 brake horse-power per cylinder. The engines referred to are the four-cycle single-acting Diesel engines of the motor ship Glenapp. The cylinders have a diameter of 760 mm. (29·92 in.) with a stroke of 1,100 mm. (43·31 in.) and run at 125 revolutions per minute. These are not experimental engines, although much work of such a nature has been undertaken and remains to be recorded. Before the war many rumours concerning Diesel engines building on the Continent for battleships were current. The facts are briefly as follow:—The M.A.N. Company, at Nuremberg, built a three-cylinder two-cycle double-acting engine, from which several thousands of horse-power were expected. The results, however, were disappointing, and a serious accident—an explosion in the scavenging system setting fire to the staging and screens erected round the engine for secrecy—which, however, concerned only very indirectly the main principles of the Diesel engine, had the direct effect on the Continent of stopping the great amount of experimental work of very similar nature in process at that time. Messrs. Krupp in Germany built a 2,000 brake horse-power double-acting two-cycle cylinder, with which no substantial success was achieved. In France Messrs. Schneider, of Le Creusot, under licence from Messrs. Carels, of Ghent, constructed a 1,000 brake horse-power single-acting two-cycle engine, regarding which no detailed results are available.

Perhaps the most successful of such units was that of Messrs. Sulzer, of Winterthur, where a single-acting two-cycle cylinder of 39·4 in. diameter by 43·3 in. stroke developed at 150 revolutions per minute, it is claimed, 2,000 brake horse-power, with a fair measure of success, sufficient, at any rate, to justify the builders in standardising a two-cycle cylinder of 600 brake horse-power with a cylinder diameter of 29·5 in. and a stroke of 39·4 in., running at 130 revolutions per minute. A six-cylinder engine of these units gives 3,600 brake horse-power, and of these several have been built for land work.

These pre-war examples indicate the progress made up to that date, and it must be admitted that the large experimental engines were generally unsuccessful, even although they were designed and built with the one and only aim of giving the maximum horse-power regardless of any other considerations such as weight, compactness, piston speed or speed of revolution. The explanation is to be found in that they were too far ahead of the knowledge at that time of this type of engine. In some cases the experiment may have been justified on the score that the information gained was applicable to and effected improvement with engines of moderate power. The *raison d'etre* of this pre-war campaign was that Germany, in many ways the home of the Diesel engine, had lagged behind with the steam turbine, but hoped by intensive development, government fostered, to regain, with this prime mover, the place she had lost on account of our progress meantime with the steam turbine. In this Germany failed, although her engine builders can claim that their largest war submarine engines showed latterly a power capacity per cylinder of nearly three times that achieved by the British standard engine.

Another landmark is the 400-500 brake horse-power submarine unit cylinder of 350 revolutions per minute, designed and built by Messrs. Sulzer during the war, with which highly satisfactory results have, it is believed, been obtained. Six-cylinder engines composed of these units have been built developing 3,000 brake horse-power per engine.

These examples indicate in a general way the various steps in the development of the Diesel engine up to the present time. The question then is, can we assess a value to this progress in comparison with the total distance required to be travelled before such prime movers can be considered for first-line fighting units of the Fleet? In view of the success of the steam turbine such a consideration will be regarded by some as unnecessary.

The Diesel engine possesses potentialities for

fighting ships that demand repeated attention in order that they may be equated to naval requirements if and when the known deficiencies are remedied. The attractions of the Diesel engine are:—Its oil economy, using the most suitable naval fuel, far surpassing the best results achieved by or predicted for the steam turbine; its readiness for immediate service without requiring warming through, &c., the relative ease with which exhaust gases can be discharged compared with these for steam plant, the better arrangements of guns and machinery due to the elimination of the uptakes and the substitution of a relatively small exhaust pipe for funnels. Against these advantages must be set against the disadvantages of small power per unit cylinder, the high weight, height and uncertainty of operation, especially with large units, under certain practical conditions.

Instancing three standard powers of naval vessels, the small battle cruiser and the battleship, and light cruiser and torpedo-boat destroyer, the first of 80,000 shaft horse-power, and the others of from 40,000 to 27,000 shaft horse-power, and assuming cylinders of 1,000 brake horse-power, 80, 40 and 27 would be required. The maximum number of Diesel cylinders in any vessel afloat is found in the "J" class submarine boats, with their 36 cylinders (three 12-cylinder engines). The maximum number of units which can be regarded as suitable is therefore relatively large. Twelve turbines and more than twelve boilers are not regarded as excessive in steam practice, and 36 cylinders in the case of internal combustion engines have, as already mentioned, proved a sound arrangement.

In respect of increase of power per unit with Diesel engines, progress, it will be seen, has been relatively slow. Up to 300–400 brake horse-power can be said to be proved at the present time to be practical politics. Higher powers still can no doubt be made to give quite satisfactory service, but the demand hitherto has been severely limited by the remarkably rapid success of the application of geared turbine machinery for vessels of all powers, down even to relatively small installations. For naval work, however, the advantages of internal combustion create an insistent demand.

Success in the past with increasing power of Diesel engines has not been achieved without encountering many difficulties. Chiefly, it must be stated, on account of insufficient attention being paid to small and intricate but absolutely essential details, of which with this type of engine there are so many. Knowledge is increasing, and a satisfactory cylinder developing 1,000 brake horse-power may confidently be anticipated in the near future. Whether, however, it will meet naval requirements or not is another matter, depending essentially on considerations of weight, space occupied, and such factors. We discussed the future of this type of prime mover in regard to these terms in an article entitled "Internal Combustion Engines for Submarines and Aircraft,"—published in Engineering, of September 20, 1918, page 319—and held that the future would see in such work much progress, as has been the case with other prime movers, notably the petrol aero engine. The internal combustion turbine also has been discussed, but still remains no more than a fervent hope.

It is too early yet to speak in any definite way of future naval policy, yet, in all probability, the efforts of the next few years, at any rate, will be concentrated upon the development of those types of fighting units that have proved themselves or have indicated the path of progress. This policy will entail considerable experiment, in which the Diesel engine will not be overlooked. Such work is always costly, and whether or not the results are dearly bought depends largely upon the method of control, the imagination brought to bear, and the careful consolidation of each step gained.

## MINIMUM TIME RATES OF WAGES AND HOURS OF EMPLOYMENT.

If the nineteenth century was the era of machinery the twentieth bids fair to become that of the humanising of industrial conditions. A review of past progress in this latter direction will show that most of the important changes for the betterment of labour have resulted from agreements mutually arrived at between employers and workers, Landmarks, however, such as the Factory Acts, stand to the credit of the responsible Governments, and undoubtedly gave a most urgently required stimulus to a strong movement for the amelioration of social conditions. The present tendency, although in measure the outcome of war conditions, is for the Government to take a larger share than in the past in settling conditions of labour. To some extent this is to be deplored.

The texts of two Bills dealing with working conditions have recently been published, and are the subject of our remarks. These measures—the one giving powers to enact minimum time rates of wages and the other stipulating hours of employment—simply ratify agreements arrived at by the Joint Industrial Committee earlier in the year. These and other such agreements bear in measure the stamp of the aftermath of the war period of national stress, from which we had just emerged when they were arrived at.

Dealing with the two measures in the order named above, it may be said that the minimum time rates of wages bill may give rise to comparatively little criticism in connection with the engineering trades, but in other industries it promises to give serious trouble. Its design is obviously to prevent "sweating" in industry, and it will, as we have said, have little, if any, effect upon the organised trades or upon engineering and its allied industries. With the 48-hours maximum week it will, we believe, be otherwise. Many difficulties can be foreseen. In respect of overtime, the difficulties imposed by this Bill are such that overtime will become very rare, inflicting thus a hardship upon the industry and upon the individual who desires to put in extra work to increase his earnings. The deterrent of stipulating for overtime in all industry a minimum payment of 25 per cent. above the standard time rate of wages might be considered sufficient to ensure that overtime would not be insisted upon by employers to such an extent as to be a detriment to the leisure of the worker.

The trades unions can be relied upon to ensure that overtime is not generally worked when their is any appreciable measure of unemployment, although in the case of breakdowns or repairs to plant, overtime can only be avoided by working short time in the case of the men using such plant—unless other plant be available, which cannot generally be the case—or by paying time rate wages to the men standing idle until such time as the plant is repaired. Provision for such cases is made in the Bill. It is desirable, in view of the restrictions put upon industry by trades unions, that the Bill should specifically state that overtime may be worked, without trades union hindrance in all such necessitous cases.

The need at the present time is for a big increase of productiveness, and if working longer hours than the normal in the case of certain willing individuals is prohibited, a loss of output will result. The earning capacity of many energetic workers whose energies cannot be absorbed in 48 hours per week, undoubtedly will be restricted. Forty-eight hours is approximately 29 per cent. of the total week (including Sunday), or 33 per cent. of the week excluding one day of rest. It can be anticipated as an outcome of this measure, provided it is passed in approximately its present form that there will be a number of workers who will seek evening employment to a considerable extent, as has proved to be the case in France; or who may even set up individually or collectively small shops for themselves, to a much larger extent than hitherto. Even with the 54-hour week this was not an uncommon occurrence. Possibly this issue has been considered, and it is desired to stimulate such efforts. The trend of industrialism at the present time does not make from the national standpoint, for the efficiency of such small, scattered and unorganised production.

How many engineers of the present day, when serving their apprenticeship, not only worked the 54-hour week, but during the majority of the months of the year attended evening classes and spent time in preparation for such classes? We do not advocate the continuance of this system of training, but simply point to this example as showing the energy available after 48 hours per week has been worked in the shops or factory. Dealing with apprentices and young workers, a point arises in connection with this stipulation of a maximum week of 48 hours. The present working hours are 48, 47, or 44 per week in many industries. The Education Acts recently passed call for 320 hours instruction per annum in the case of young workers. This instruction is not to take place outside the period of from 8 a.m. to 7 p.m. Roughly, this means 8 hours instruction per week for 40 weeks in the year. It is quite possible, without any hardship, for part of this instruction to take place outside the normal working hours. Such time will not be paid for by the employers. Thus, 44 hours work, 4 hours instruction within working hours paid for at time rates, and 4 hours outside. Is this a hardship? It means 52 hours per week, and as such, will it be allowed under this 48-hour Bill? We do most definitely state that the organisation of useful and health-giving recreations through suitable clubs for young workers and the like has not yet reached such a stage, nor yet will attain to such efficiency for a number of years, that freedom and leisure resulting from the total abolition (between the ages of 15 and 18, under the new Education Acts) of all instruction outside 48 hours will be positively harmful to the individual and detrimental to the maintenance of production during necessitous years. This point must be emphasised.

In regard to the exemption from the provision of this Act, definition is required of the clause: "Persons employed in a confidential capacity who are not actually employed on manual labour." If junior clerks are included in this category, some other provision should be made for this class of employee, which is perhaps more in need of protective legislation than most of those with whose case the Bill is designed to cope.

Unless it be that, through the League of Nations and the International Labour Regulations arising from its successful operation, the great industrial countries fall rigidly into line with us, we shall find that such provision as we are now making to accommodate the claims of Labour will surely and effectively influence adversely our prospects of maintaining our industrial supremacy.

## RAILWAY NATIONALISATION IN JAPAN.

The control of the privately-owned railways during the war, both in this and in other countries, has brought the questions of national ownership and management prominently before the public. In the United States of America, there seems to be little doubt as to the unfortunate financial results which have attended Government management, while in Canada the Government was apparently forced to take over the control of thousands of miles of track because the companies were quite unable to carry on. Bare facts like these provide room for unlimited argument. Given a good strong prejudice, either for or against national railways, any desired conclusion may be arrived at. If, as some contend, the duty of a Government is limited to making and enforcing laws and defending the country, then the management of railways is none of its business, but neither are the postal nor telegraph services. If, on the other hand, one holds the view that all monopolies should be held by the State for the benefit of the people then railways and canals should be among the first objects of nationalisation. The question really is one of expediency, and not of principle at all. A State could flourish under either system. But the ever-increasing tendency towards the amalgamation of rival trading concerns points to the economic advantages derived from a unified control, and this has led to a claim that more efficient railway operation would be possible if British lines were worked as a single system. Many, however, especially those who are conversant with some of the features of "big business" on the other side of the Atlantic, would hesitate to permit so huge a monopoly to be held by any private interests on account of the political power they could exert. We are, fortunately, free, as yet, from systematic "lobbying," and we desire to remain so. The only alternative to private control of a unified system is State control, yet if this

should mean the abandonment of ordinary commercial principles and handing over the conduct of the railways to an army of anonymous permanent Civil Service officials, unreachable by criticism, whose promotion comes by seniority, and whose one desire is to avoid the responsibility of doing anything, it will be bought at a disastrous cost to the industrial life of the country.

As we have now come to a time when the nationalisation of our railways in some form or other is being seriously contemplated, it is of interest to examine the results which have attended the operation of the Japanese railways which were taken over by the Imperial Government more than ten years ago. Railway construction in Japan dates from 1870, when British engineers started work on the Shimbashi-Yokohama and Kobe-Osaka sections of a trunk line projected by the Government to link up the principal cities. Money, however, was difficult to raise, while a domestic rebellion and the Formosan expedition also hindered development, so that by the end of 1882 there were only 115 miles of railway in operation. These lines were owned by the Government, but the Treasury being unable to provide sufficient capital for further construction, private companies were given concessions for railway enterprises, and were encouraged by subsidies and guarantees from the State. All concessions, however, contained a State-purchase clause and the Government exercised supervision over all construction work, accounts and rates. In the year 1900, acting upon the findings of a committee, the Government introduced measures for the nationalisation of the railways, but these failed to pass, and in their place laws were enacted clearly defining the policy of State control over private enterprise and consolidating the powers of the Minister. Public opinion, by this time, was favourable to the principle of Government ownership, but much divided on the question as to whether Government administration could be so efficient as private management. The outbreak of hostilities with Russia in 1904, distracted the attention of the nation from domestic matters, but with the successful termination of the war two years later, the policy of railway nationalisation was placed in the forefront of the reconstruction programme of the Government.

It is worth while considering how matters stood at that time. According to the annual report of the Imperial Government Railways of Japan for the year ending March 31, 1917, there were in the country a total of 4,800 miles of railway open for traffic in March, 1906. Of this length, 3,250 miles were divided amongst 38 different companies, and the lines were mostly short and disconnected. Government lines were sandwiched in between those of private companies, and the want of co-ordination made the cost of service unreasonably high and rendered the proper development of through traffic out of the question. Everything pointed to State ownership and operation as the only solution to the problem, and a Railway Nationalisation Bill passed into law on March 31, 1906. The purchase price was fixed as "A sum equal to 20 times the amount obtained by multiplying the cost of construction at the date of purchase by the average rate of net profits on the cost of construction during the six semi-annual business terms of the company ending the first half year of 1905 inclusive." To this sum was to be added the value of the stores owned by the companies, who were to be paid in bonds bearing interest at 5 per cent. Seventeen companies, owning between them 2,823 miles, were bought out an aggregate cost of over 484,000,000 yen, the purchases being accomplished between October, 1906 and October, 1907. The officials were all given the option of remaining in the service.

It would appear, from the Report we have mentioned, that the first few years of Government ownership have been marked by a good deal of indecision as to the most efficient means of managing their newly-acquired undertaking. The old system of centralisation which had served well enough for the comparatively small mileage previously owned by the State proved inadequate, and at the end of 1908 the railways were removed from the control of the Minister of Communications, and handed over to a newly-created Railway Board, which was made directly responsible to the Minister-President of Railways. The administration, moreover, was de-centralised, the system being divided into five areas, each division being a complete unit under its own executive head, who was invested with broad powers within his particular area. This scheme, as one might imagine, did not secure that unity of control and standardisation of practice which were so desirable, and in 1910 we find another reorganisation taking place. Bureaucratic methods, which had developed, had to be eliminated, and to this end the Traffic and Finance Departments were substantially abolished, the chiefs of the various sections being brought into direct touch with the President. A council, of chief railway officers sat daily to dispose of items of routine management on the spot, a council of directors sat twice a week to deal with larger questions of general policy. This method of administration endured until 1913, when these two councils were abolished together with the "Commission of Investigation." The director of the Technical Department was then made responsible for all technical matters, and the same official was also placed in immediate control over the various railway workshops which were formerly managed by the Divisional Superintendents. The principle of centralisation was further emphasised by the creation of a Controller of Railway Stores, whose duty it was to look after the purchase and distribution of stores for the entire system. One would have imagined that by this time the most satisfactory system of administration would have been discovered, and the railways would have settled down without further trouble, but in 1915 a further re-organisation was considered necessary. The local stores and workshops again reverted to the control of the Divisional Superintendents, and the sections of the Technical Department which were abolished two years before, were again established. Thus the pendulum has swung between centralisation and de-centralisation of management, the defects of each always making the other seem preferable.

Details of management, however, are matters which every country that adopts State ownership must work out for itself along lines which will be determined by national characteristics and particular conditions. More interesting are the broad results which have followed State ownership and operation. The first thing to be expected would be a standardisation of rolling-stock and equipment, with a consequent vast economy in manufacture and maintenance. This result has been largely attained in Japan. Three standard types of locomotive have been decided upon, and all new locomotives are built according to these standards, with the exception of a few of the 0-10-0 type necessary for certain extremely heavy mountain grades. Standardisation gave an immense impulse to the infant locomotive building industry of the kingdom, and hundreds of engines have now been built in the country. The modern engines show a great advance on their predecessors, both in weight and power, while superheating has been adopted in all engines built since 1914. Nor has the Government been backward in developing electric traction, which is specially suitable for a country like Japan, where the railways traverse mountainous regions with very heavy grades. In 1908, there were on the Central, the Yamate, and the Tokyo-Yokohama lines 26 cars, with a seating capacity of 1,040 and a car mileage of 409,664. By 1917 the cars numbered 125, the seating capacity had increased to 10,984, and the mileage to 6,496,096. The power consumed rose from 1,151,692 kw.-hours in 1908 to 14,569,041 kw.-hours in 1917. In addition to this development, the Government undertook the electrification of the Abt rack-railway across the famous Usui pass, which involves a climb of 1,817 ft. in 6·9 miles. The electrified line was opened in 1912, and it was proved to be possible for a couple of rack-locomotives to pull 14 cars up a grade of 6·7 per cent. for 5½ miles, a feat unexampled anywhere in the world at the time. This railway has 12 locomotives and consumes about 2,500,000 k.w.-hours per annum.

The unification of control, brought about by nationalisation led, as might be expected to a complete re-organisation of the railway workshops with a view to increasing their efficiency. The railway management were able to readjust the distribution of work among the various plants, thus permitting specialisation and quantity production. These features were further encouraged by the standardisation of designs to which we have referred. The net results obtained by the re-organisation were very remarkable. Comparing the year 1911 with 1917, the latter year witnessed an increase of 45 per cent. in the tonnage of locomotives repaired, of 35 per cent. in the seating capacity of the carraiges repaired, and of 65 per cent. in the capacity of the wagons repaired, yet in spite of this increase of something like 50 per cent. in the work done, the labour-hours expended were actually less by 0·3 per cent. than they had been seven years previously. A similar increase of efficiency, although more difficult to demonstrate by means of figures, was brought about by the consolidation of the railway stores. Much of the stock taken over from the companies was obsolete, or rendered so by the standardisation introduced throughout the system. This had to be disposed of at a loss. The stocks which had to be carried, however, were vastly reduced. The purchase of stores by free contract with suppliers, instead of by tender, was legalised in 1906 in order to give an elasticity to the purchasing agent which was impossible under the alternative procedure. In 1908, the freedom of purchase was still further enlarged, and now all railway requirements are obtained by free contract. The Government are to be congratulated on having sufficient confidence in the integrity of their officials to entrust them with the responsibility of purchasing where they consider they can do so to the best advantage. Moreover, the method appears to be justified by its results, for ability is said to be fostered, while supply and demand are kept in better harmony. Purchase of all classes of stores which can be most advantageously bought by the various divisional offices is left to them, the central office only buying goods from abroad, stores which may affect railway finance, or those which it is desirable to buy in bulk to avoid the effect on the market of the competition of the divisional purchasing agents. The policy of decentralisation of purchasing is, in fact, followed as far as possible.

The success or otherwise of the Government management of the railways must be judged not so much from the greater efficiency which any kind of unified control must bring about, but rather from the financial results of their operation. Any method of comparison with company management is open to objection unless the respective results are themselves judged in the light of all the circumstances at the time. If the Government has reduced costs per ton-mile, we want to know whether the same standard of service has been maintained, and if this is agreed, it may yet be contended that a company having the same facilities as the Government would have provided even better service. To arrive at any useful conclusion it is necessary to study closely and impartially the pages of tables and other data contained in the report. Generally we may say that the financial results of the railways under Government management have shown a tendency towards steady improvement. Before nationalisation, the original State lines had an average ratio of expenses to earnings of 48·6 per cent., and showed a profit on capital of 7·1 per cent. The company lines had a ratio of expenses to earnings of 46·7 per cent. and yielded a return of 7·82 per cent. Thus the company lines showed the better result, but it should be remembered that the Government owned a large proportion of mountain track, costly to operate and expensive to construct. After consolidation the average ratio of expense to earnings for the whole system has fluctuated from 52·8 in 1909 to 42·3 in 1917, the average for the ten years of nationalisation being 47·7 per cent. Costs of labour and material rose greatly during this period. In order to show the growth of the traffic on the system now owned by the Government, some significant figures are given below, the years

chosen for comparison being 1905-6 and 1913-14, as the effect of the European War influenced the returns subsequent to the latter date.

| Item. | 1905-6. | 1913-14. | Inc. |
|---|---|---|---|
| Average route mileage worked | 4313·9 | 5348·1 | per c. 24 |
| Number of passengers carried | 97,701,960 | 167,773,143 | 72 |
| Tonnage of goods hauled | 20,278,673 | 36,348,362 | 79 |
| Passenger miles | 2,381,339,652 | 3,690,964,619 | 55 |
| Ton-miles | 1,333,378,644 | 3,053,852,638 | 130 |
| Earnings per mile (yen) | 15,360 | 20,799 | 35 |

The profit earned by the State railways has averaged 6·01 per cent. for the last eight years, the extreme figures being 5·1 per cent. in 1910 and 7·2 per cent. in 1917. The Government, however, charge to revenue account part of the cost of additions and betterments, and also the expenses of supervision over the tramways and remaining private lines. Including these charges the net profit has averaged 5·74 per cent. over the eight years in question.

A further comparison of the conditions before and after nationalisation is given by the table below, which shows the increase or decrease in various items of expense.

| Item. | Percentage to Total Expenses. | | |
|---|---|---|---|
| | Average 5 years before Nationalisation. | Average 10 years after Nationalisation. | Increase or decrease. |
| General expenses | 8·3 | 2·6 | Dec. 5·7 |
| Maintenance of way | 21·7 | 23·2 | Inc. 1·5 |
| Maintenance of equipment | 13·0 | 15·7 | Inc. 2·7 |
| Total maintenance | 34·7 | 38·9 | Inc. 4·2 |
| Traffic expenses | 27·4 | 28·1 | Inc. 0·7 |
| Transportation expenses | 29·5 | 29·4 | Dec. 0·1 |
| Total cost of service | 56·9 | 57·5 | Inc. 0·6 |
| Miscellaneous | — | 1·4 | Inc. 1·4 |

The striking saving in general expenses is due to the reduction in the cost of directors and office staff brought about by consolidation. Maintenance costs are higher, largely on account of the extra price of material and labour, although it is interesting to note that the specialisation of workshops possible under unification of management has increased their efficiency to such an extent that the average repair time for passenger coaches has been reduced from 33 days to 19 days, and for goods wagons from 30 days to 8 days. The increase in traffic expenses is referred principally to the growth of the number of stations, from 1,153 to 1,668, and to the improvements in accommodation. On the other hand, the traffic expenses per passenger-ton-mile have steadily decreased since 1910. Transportation expenses show a fractional decrease, which is accounted for by the great economy effected in the consumption of fuel and oil by the provision of more efficient locomotives. Fuel and oil together are responsible for more than half the total transportation expenses. The fuel cost alone has been reduced from 0·166 yen per engine mile or 1·124 yen per 100 car-miles in 1908 to 0·122 yen and 0·630 yen in 1917 for the respective items.

Efficiency of operation may be defined as making the most use of existing equipment, and judged on these grounds, the Government management appears to have justified itself. In 1908 an average of 25·8 trains, 153·5 passengers and 284·0 goods wagons were handled per day per mile, whereas in 1917 the comparative figures are respectively 30·4 trains, 186·8 passengers and 433·2 goods wagons. Passenger traffic increased during this period by 81 per cent., and goods traffic by 190 per cent., yet these increases were handled by only 56 per cent. more coaches and 85 per cent. more wagons. Nor were the passengers more crowded, in fact the seating accommodation per passenger was greater at the end of the period. The figures for the goods traffic, however, show that an increase of only 60 per cent. in train-miles was sufficient to cope with the extra 190 per cent. of tonnage, and train-loads were, in fact, increased from an average of 71 tons in 1908 to 128 tons in 1917. This implies a great saving in operating cost, and a further evidence of improved management is shown by the fact that the proportion of empty car-mileage was reduced from 26·4 per cent. to 23 per cent. of the total car-miles. Greater efficiency in the repair shops, moreover, permitted 93 per cent. of the total passenger cars and 95·8 per cent. of the goods wagons to be in service on the average during 1917, whereas the corresponding figures for 1908 were 86·4 per cent. of the passenger cars and 92 per cent. of the goods cars.

A perusal of the Report indicates that the Government authorities are enterprising in the direction of extending conveniences to the public. A cash-on-delivery system was introduced for goods in 1915, and it is now possible for the consignee to appoint the time and place for delivery of merchandise and to pay for it at his own business address. The Government have also recognised the fairly obvious fact that the consignee has ultimately to bear transportation charges on goods which he buys, and that it is a cumbrous system for the consignor to pay the freight to the railway and then recover it from the customer. Hence the Japanese railways carry all charges forward to the consignee, except freight on car-load lots, and this has been found beneficial in facilitating business. An express parcel service with free delivery is available to the public, and a fast freight service at special rates is provided for the convenience of shippers. The mere passenger has also benefitted by the consolidation of the railways, as he now travels cheaper, faster, safer and more comfortably. In addition to ordinary season tickets, cheap 90-day commutation tickets, available for any member of the purchaser's household, are conveniences we would welcome in this country. Steam heating has been extended to all passenger and mixed trains, good dining and sleeping-car services, for both first and second-class are general, while the daily "train de luxe" between Tokyo and Shimonoseki carries private rooms, an observation parlour, and other luxuries.

From these, and other facts given in the report, it is clear that no charge of lack of enterprise can be fairly levelled at the Japanese railway management. Nor does the inefficiency which is generally associated with Government undertakings, seem to have infected the department. On the other hand, praise is justly due for the results obtained, and there can be no question that the citizens are far better served at the present time by the State railways, than they would have been had the previous system of independent companies been allowed to continue. The excellence of the report, with its 200 odd pages of data and diagrams is in itself an evidence of efficiency, and would never have been produced by a Government Department whose organisation was bad or whose officers were incompetent.

## THE IRON AND STEEL INSTITUTE.

THE autumn meeting of the Iron and Steel Institute was opened yesterday, and is being continued to-day in the Hall of the Institution of Civil Engineers. In the enforced absence of the President, Mr. Schneider, who is going to the United States on behalf of the French Government, the chair was taken by Sir Robert Hadfield, Bart., who stated that His Royal Highness, the Prince of Wales had accepted the Honorary Membership of the Institute, thus giving another proof of his energy.

At yesterday's meeting the chairman presented the Bessemer medal for 1919 to Professor Cav. Federico Giolitti, Ph.D., Turin, stating that it was decided last spring by a unanimous vote of the council to award it to him this year, but the presentation could not take place at the May meeting in accordance with the usual custom, on account of Dr. Giolitti's unavoidable absence. The chairman briefly explained Dr. Giolitti's career, and stated that in 1908 he was appointed Professor and Director of the Laboratory of Metallurgy and Metallography at the Turin Royal Polytechnic Institute, where he carried out valuable work in connection with the cementation of steel, and published a book and reports on the subject. Later, the well-known firm of engineers and shipbuilders, Messrs. Gio. Ansaldo and Co., secured the services of Dr. Giolitti in the capacity of managing director, this giving further scope for his great talent. His work on the heat treatment of mild and medium hard steel for engine construction had since been issued and had become authoritative. Further, in deciding to honour Dr. Giolitti, the Institute felt that a tribute was also due to Italian metallurgists for the ingenuity and perseverance they had displayed during the war in overcoming the extreme difficulties they encountered in regard to munitions supplies.

Dr. Giolitti, in the course of his reply, expressed his thanks to the Institute and referred briefly to the difficulties encountered by the Italian Army and Navy at different periods during the war in keeping up their supplies of material, a work which received the unremitting efforts of all the Italian metallurgists and engineers.

Sir Robert then announced that the Council had decided at their meeting that morning, to send a telegram to the President of the James Watt Centenary Committee, Birmingham, to present the congratulations of the council or of the members, they having in their minds the vast debt which all the world owed to that celebrated Englishman.

The meeting then resolved itself into a general conference on fuel economy, under the auspices of Committee No. 1 on Fuel and Ores. The reports and papers on this subject mentioned in the programme, together with others which were received ultimately, were read and discussed; they took up the whole of yesterday's morning and afternoon sessions. We commence the reproduction of several of these reports and papers in another part of the present issue, and shall deal in detail with the proceedings in our next.

ROADS AND TRANSPORT CONGRESS AND EXHIBITION.—A roads and transport congress and exhibition is to be held at the Royal Agricultural Hall, from November 20 to 27 next. The undertaking is to be held under the auspices of the County Councils Association, which is being supported by the Association of Municipal Corporations, the Urban District Councils Association, the Rural District Councils Association, the Institution of Municipal and County Engineers and the County Surveyors' Association. A comprehensive programme of papers to be read has been arranged, while the exhibition is expected to prove of considerable importance, the whole of the main hall having already been booked. Arrangements have also been made with the Institution of Municipal and County Engineers to hold a housing conference on November 27 and 28, and it is hoped that a Public Works Exhibition may be arranged for. A further activity in connection with the matter will be a conference of the London "Safety First" Council on Saturday, November 22, and Monday, November 24.

BRITISH WORKMANSHIP IN AEROPLANES.—Of great interest as proving the period of serviceability of a properly-constructed aeroplane, and incidentally one of the most noteworthy tributes to the unrivalled position of British design and construction, is an example which has been brought to the notice of the visitors to the Amsterdam Aeronautical Exhibition, and is recorded by the Federation of British Industries. In an aerodrome adjacent to the exhibition is a "Bristol" Fighter delivered by the constructors in September, 1917. It was then immediately put into commission under active service conditions, and after doing considerable work unfortunately landed in Holland. The pilot was interned and the machine was soon afterwards bought by the Dutch Government. Though it has been continuously flown by Dutch officers it has never been repaired or renovated in any way, and every unit is exactly as when it left the "Bristol" works. Even the "Cellon" dope has never been renewed. The machine is still in service and in great favour with the Dutch pilots.

SOUTH AFRICAN TECHNICAL SOCIETIES AND STANDARDISATION.—In the course of his presidential address before the South African Institution of Engineers, at their meeting on July 16, Mr. W. Elsdon-Dew, M.I.E.E., stated that he believed one of the most important matters calling for the attention of technical societies was that close co-operation which tended to greater efficiency. The closer working together and the joint housing of technical and scientific societies on the Rand were questions which required special consideration. In this connection, he mentioned that the work of the Standardisation Committees dealing with the subject of standards which should be adopted for South Africa would have for effect to put all work on a proper footing, so that requirements could be met on equal grounds. The possession of proper standards to work to was a most important factor in engineering practice, and South Africa could safely follow in the footsteps of the British Engineering Standards Association. The work of standardisation was of an arduous nature and would involve yet a large number of discussions, of which South African committees had already had their share; he sincerely hoped that much good would come out of these discussions in the near future.

## THE JAMES WATT CENTENARY.

THE celebration of the centenary of the death of Watt inaugurated at Birmingham on Tuesday last, has already achieved a success upon which the Centenary Committee may well be congratulated. Opened in a felicitous speech by the Lord Mayor (Sir David Brooks), the proceedings have passed off without a hitch. The first part of the programme included lectures on Tuesday forenoon by Professor Burstall and Professor H. S. Hele-Shaw. The attendance was good, and a distinguished company included Major Gibson Watt, a grandson of the daughter of Watt, and Miss Boulton, a direct descendant of Matthew Boulton. Also conspicuous at various functions of the day were Sir Oliver Lodge, Engineer Vice-Admiral Sir George Goodwin, K.C.B., Engineer-in-Chief of the Navy, Col. Barraclough (Australia), Professor Rateau (France), Mr. W. Sandford Riley (United States), Col. Sir Gilbert Barling, Professor Sir William Ashley and Professor Turner of the University of Birmingham, Professor Takemura of Tokio University, and many representatives of other universities and learned societies, together with Mr. William Mills, Mr. Askquith Ellis, the Chairman and Honorary Secretary to the Executive Committee, and a number of local supporters of the centenary movement.

The objects of the Centenary Committee are to raise funds for the endowment of a "James Watt Chair" in the University for the promotion of research in the production of power, to erect a suitable building for the housing of the splendid collection of portraits, drawings, models, letters, &c., referring to Watt, Boulton and Murdock, and to publish a memorial volume, and these were all dwelt on by the Lord Mayor, who recalled to the audience the generous gift to the town by Mr. George Tangye, of the Boulton and Watt Collection in the Reference Library.

Professor Burstal took for the subject of his lecture "The Rise of Engineering Manufacture," while Professor Hele-Shaw dealt with "James Watt and Invention," suggesting that the proposed chair should be one devoted to invention, a proposal which, no doubt, will be fully considered by the Committee. These addresses will, it is understood, be published in full in the memorial volume.

Among the interesting events of the morning was the presentation to the Lord Mayor of a beautifully illuminated address from the Norges Tekniske Soiskole in Trondjhem, which read as follows:—

"On the occasion of the centenary of the close of life of that illustrious engineer, James Watt, and in full appreciation of the importance to all mankind of his work, the Rector and Senate of Norges Tekniske Soiskole in Trondhjem tender their most heartfelt congratulations to the British nation that owned him and to the city of Birmingham, that scene of a great part of his ardent labours and his final resting place. The name of James Watt will for ever command a prominent place among the names of the foremost pioneers of applied engineering, science, and his achievements will be honoured not only for the genius which they display but also as a corner stone in the foundation of modern civilisation."

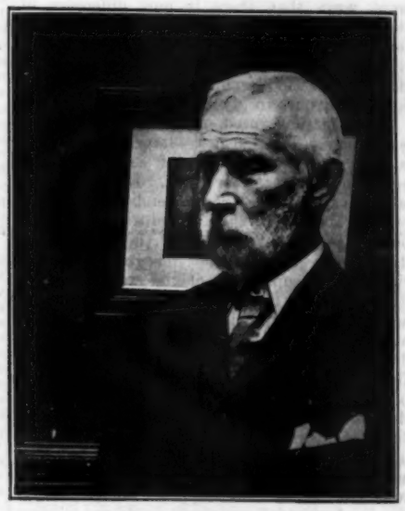
The Secretary (Mr. R. B. A. Ellis) also read a telegram received from Rector Hije Professor Arentz, of Trondhjem, asking the Committee's acceptance of the address above quoted as a token of the veneration felt in Norway for the memory of James Watt.

The other events of the day were an impressive Memorial Service in Handsworth Church, a Garden Party in the grounds of Heathfield Hall, and a reception by the Lord Mayor in the beautiful Art Gallery of the city. At the Memorial Service—which opened with the little-known hymn of Joseph Addison, "The spacious firmament on high," the anthem was taken from the words of Ecclesiasticus, "Let us now praise famous men," while Canon Barnes, Master of the Temple, delivered a masterly address on the life, character and work of Watt and the influence of the discoveries of Watt in the happiness of humanity. After the conclusion of the service opportunity was given to all present to visit the Watt Chapel which stands on the south side of the chancel, and to inspect the beautiful Chantrey statue of Watt, one of the masterpieces of the great sculptor.

During the latter part of the afternoon, while the company were at Heathfield, by the courtesy of Mr. George Tangye, as many visitors as desired were able to climb the narrow stairway to the famous garret workshop which, for a hundred years, has remained just as the master hand left it. We reproduce a photograph of this workshop on the present page, and we also annex a view of Heathfield Hall and a portrait of Mr. George Tangye, to whom engineers all over the world must feel indebted for his action in doing so much to preserve the records and relics of James Watt.

The commemoration proceedings were continued yesterday, and we shall deal with them more fully in our next issue, when we shall also give an account of the most interesting exhibition of Watt relics arranged by the Exhibits Committee in a gallery of the Art Gallery.

HEATHFIELD HALL.



MR. GEORGE TANGYE.

JAMES WATT'S WORKSHOP AT HEATHFIELD HALL.

# LITERATURE.

*Reinforced Concrete—Theory and Practice.* By FREDERICK RINGS, M.S.A., Architect and Consulting Engineer. Second revised and enlarged edition. London: Batsford, Limited. [Price 10*s.* 6*d.* net.]

REINFORCED concrete appears to have attractions both for those who make of it a profound study, and those also whose acquaintance with it may never be more than superficial. This quaint combination of materials, regarded at the outset with some suspicion, has proved its value in so many different ways that there is now difference of opinion only as to the measure of its advantages, its applicability to this or that class of structure, and its durability.

The author of the present work, now in its second edition, endeavours to give both practical instruction in the methods used, and in the theoretical basis of design. The first part—largely borrowed—deals with the proportioning of concrete, plant commonly used, and timber forms. Exception may be taken to the author's recommendation that the cement-mortar binding the aggregate together may be but 10 per cent. in excess of the voids to be filled. This is a somewhat meagre allowance, providing for a separation of the stony material of little more than 3 per cent. of linear dimensions of the voids, even if the mortar is evenly distributed throughout the mass, which cannot be assured, particularly where hand mixing is relied upon. Dealing with carpenter's work, there is unfortunately introduced a table of the "safe" strength of struts for floor forms, giving unit stresses in compression for long members, which, as to some dimensions given, it would be very ill-advised to adopt. The author's allowance of 10 per cent. for waste ends of rods cut on the site, appears somewhat extravagant of material, and might easily run to some hundreds of pounds—in money—on any considerable work. This may be practically eliminated if fully detailed drawings are prepared before "listing" steel. With these qualifications this part of the book will be of use to those having but little previous acquaintance with reinforced concrete construction.

The second part, dealing with the principles of design, is somewhat unequal in treatment, but on the whole sound. The formulæ relating to continuous beams are less intelligible than they should be, as the sketch figures given are not lettered to correspond with the symbols used in the formulæ. On page 90 the diagram giving shears and moments for uniformly-loaded beams of many spans, needs some notes to make it useful.

The derivation of formulæ in common use, is in some cases wanting in lucidity, due perhaps to condensation of the detailed working, and a lack of connecting explanatory matter, but the results reached, in those cases which have been checked, appear to be correct.

With respect to some of these expressions it may be said that though the methods of reinforced concrete design must be substantially true, and properly understood, any great refinement in figuring may be labour lost in the case of a material which varies so much in its properties, and is so greatly affected by the care, and degree of skill, used in construction.

The precise determination, for instance, of the neutral axis of a beam—on the usual basis of design—is of little value, this axis being a purely hypothetical position, so that simple approximate formulæ will commonly give results having as good a claim to practical utility. Exception must, however, be taken to the treatment of concrete-embedded joists, which is not satisfactory. Calculations for shear members, and for columns, centrically and eccentrically loaded, are considered with a fair measure of completeness, following which the author deals with arch design, by methods that are simple, and generally no doubt sufficient.

Retaining walls, circular structures, and domes, are also shortly treated. For the assistance of the reader needing such help, a few well-selected worked examples are given, and should prove helpful, bringing this part of the book to a close. The London County Council regulations for reinforced concrete construction are included, and sundry useful tables. It is to be noticed with approval, that a tabulated list of symbols is given at each end of the book, and that two loose sheets displaying diagrams for ready designing of slabs and beams are furnished, in addition to similar sheets bound in. The work is well illustrated, and though calling for no special commendation, will no doubt be useful.

## DEVELOPMENT OF GEARED TURBINES FOR THE PROPULSION OF SHIPS.*

By MR. R. J. WALKER.

ALTHOUGH the successful application of the steam turbine to marine propulsion dates back to the year 1897, when Sir Charles Parsons demonstrated in that now historical vessel, the Turbinia, the great advantages of the turbine system when applied to the propulsion of ships, it is only within the last few years that mechanical reduction gearing has been largely adopted in association with steam turbines.

Sir Charles Parsons always had in mind the possibility of reduction gearing in connection with the application of his steam turbine to marine propulsion, and even as far back as 1897 a small launch was constructed in which helical gearing similar to that adopted by Dr. De Laval, of Stockholm, with his high-speed turbines for land purposes, was introduced between the turbine and the propeller. This is believed to be the first application of helical gearing to drive a propeller.

It was considered desirable, in view of the very wide field which was opened up by the success of the Turbinia for the application of direct-driven turbines to high-speed vessels, to confine attention for a time to development in this direction only, and to defer embarking on the additional pioneer experimental work incidental to reduction gears of unprecedented size. The wisdom of such a policy was subsequently shown by the great difficulty experienced at the commencement in introducing the turbine system of propulsion against the conservatism of British engineers and shipowners who looked upon such a revolution in the methods of marine propulsion with a great amount of doubt and distrust. Very little experience existed at that time of the accurate cutting of toothed gearing in large sizes, and the additional work involved would certainly have added to these difficulties.

Before proceeding to consider the development of geared turbines, it may be of interest to briefly review the progress made in connection with direct-driven turbines.

Following on the success of the Turbinia, the torpedo-boat destroyers Viper and Cobra were built and fitted with turbines for the Admiralty in 1899, and achieved remarkable speeds.

The next step in the case of war vessels was when the system was fitted to the third-class cruiser Amethyst, three other sister vessels being fitted at the same time with reciprocating engines. The results of these trials demonstrated the economy of the turbine in this class of vessel, more especially at the higher powers, and influenced the British Admiralty in deciding to have the battleship Dreadnought fitted with turbine engines. The keel of this vessel was laid down at Portsmouth in October, 1905. By 1906 the British Admiralty had adopted turbines for all new construction.

In the early endeavours to introduce the turbine for commercial purposes, no shipowner could be found bold enough to make the experiment on any reasonable terms. It was ultimately recognised that the only chance of convincing shipowners of the practicability of such a proposal was to build a vessel specially for the purpose, and Captain John Williamson, Messrs. Denny Brothers, and the Parsons Marine Steam Turbine Company, Limited, undertook the financial responsibility of building the Clyde steamer King Edward, which was first put into service in the summer of 1901, and has been running satisfactorily ever since that date. Other vessels very quickly followed the King Edward, until at the present time the total shaft horse-power of turbine vessels on service for commercial purposes is about 1,600,000.

One of the chief difficulties which had to be met in applying the steam turbine to the propulsion of ships arose with the propellers. As is now generally known, it is desirable that a turbine for maximum efficiency should run at a high rate of revolution, whilst on the other hand, for maximum propeller efficiency, much lower rates of revolution are necessary. Obviously one solution was by the introduction of some form of gearing between the turbine and the propeller; the time, however, for such a departure, for reasons already mentioned, had not then arrived. The problem was therefore to reconcile as far as possible those two opposing factors, and to arrive at the best compromise to meet the conditions required by a suitable lowering of the revolutions as then designed for land turbines, and a raising of the revolutions of the propeller by suitable modifications in the form. This was one of the most serious problems which had to be faced in the design and construction of the Turbania, and led to many modifications in the propellers and turbines of that vessel before success was finally achieved.

With the raising of the revolutions of the propeller the diameter and pitch ratios were less, whilst the ratio of blade surface to disc area was much greater than is usual with propellers driven by ordinary reciprocating engines.

It was found as a result of numerous and costly experiments that a judicious compromise could be, and was, arrived at, whereby satisfactory combined efficiencies of turbines and propeller were obtained for high-speed vessels, resulting in increased speed of ship and increased economy in coal consumption.

The chief governing factors in marine steam turbine designs are those of economy, weight, and first cost, and it was found in actual practice that the problem of applying the turbine direct to the propeller was for the time satisfactorily solved to fulfil these conditions for vessels of about 18 knots speed and upwards.

Up to the year 1909 the steam turbine had not been applied to vessels of slow and intermediate speeds, with the exception in a few instances of the combination of reciprocating engines with a low-pressure turbine.

From the early years of steam turbine design, it became apparent that the turbine engine was capable of economically dealing with ratios of expansion beyond the limits possible with reciprocating engines, and a combination of reciprocating engines with a low-pressure turbine presented advantages as regards economy in that class of vessel where the designed full speed fell below the range suitable for an all-turbine arrangement, that is to say, for vessels of about 18 knots speed and under, the reciprocating engines in such an arrangement working in the region of pressure drop where the conditions are best suited to it, and the turbine utilising that portion of the expansion diagram which the reciprocating engine is not able to utilise efficiently. The service results of vessels fitted with this combination system have shown that this arrangement of machinery effected a saving of from 12 per cent. to 14 per cent. in coal consumption as compared with similar vessels fitted with quadruple engines.

It was not until the success of the marine steam turbine had been assured by its rapid adoption in vessels of moderate and high speed, and more time was available, that attention was directed to the application of the turbine to slow speed vessels by the introduction of gearing between the turbine and propeller. Several forms of gearing have been proposed, such as electrical, hydraulic, and mechanical. Electrical and hydraulic transmission gear have been fitted in a few ships, but the greater majority of vessels have been fitted with mechanical gearing.

In view of the success obtained by Dr. De Laval, of Stockholm, with helical and double helical gear in connection with his turbine for land purposes for powers up to about 600 brake horse-power, Sir Charles Parsons decided to test turbines mechanically geared to the screw shaft. Even at this stage there was encountered a very strong prejudice to gearing, and it was found necessary, in order to test its practicability for marine work, to carry out experiments in a cargo boat.

In 1901 an old steamer, the Vespasian, was purchased and fitted with geared turbines in place of her original triple-expansion reciprocating engines, but before the change was made exhaustive trials were carried out with the original engines. Full particulars of the results of the comparative trials of the two systems of machinery were given in a paper by Sir Charles Parsons read before the Institution of Naval Architects in 1910. It will be sufficient here to state that an additional economy in coal consumption of over 15 per cent. was obtained in the Vespasian by the substitution of geared turbines for reciprocating engines, and that the efficiency of the mechanical gearing was found to be about 98½ per cent. The Vespasian was run between the Tyne and Rotterdam, carrying coals, and in general trade for four years, and the hull being then worn out was broken up, but the turbines and gearing, which showed no signs of deterioration, were taken out of the vessel and fitted to a new steamer, the Lord Byron.

The success of the Vespasian aroused very keen interest amongst engineers and shipowners, and Professor Sir John Biles was amongst the first to recognise the advantages of increased efficiency to be derived from geared turbines for cross-Channel steamers when he recommended the London and South-Western Railway Company to adopt geared turbines in their new steamers Normannia and Hantonia, for their Southampton to Havre service, and built by Messrs. the Fairfield Shipbuilding and Engineering Company, Limited. The trials of those vessels, which took place in the early part of February, 1912, were successful, and the ships have continued to give very satisfactory results.

The Paris, another cross-Channel steamer for the London, Brighton and South Coast Railway Company, was built a year later by Messrs. Denny and Brothers, and fitted with geared turbines, and attained a speed of 24¼ knots. After the success of these vessels, other shipowners quickly followed the lead of these companies.

Although gearing was primarily introduced to widen the field of operation by its adoption for vessels of low speed, it was soon recognised that increased efficiency could be obtained by means of reduction gearing in fast ships. The Admiralty placed an order in 1910 for the part gearing of the machinery of H.M. torpedo-boat destroyers Badger and Beaver, by introducing gearing for the high-pressure and cruising turbines of these vessels. In 1912 the Admiralty adopted gearing for the whole of the machinery of the two destroyers H.M.S. Leonidas and Lucifer, of 22,500 h.p., fitted on two shafts.

Exhaustive trials of these vessels were carried out, the results of which showed a considerable increase in efficiency both at full and cruising speeds as compared with previous torpedo-boat destroyers with direct-driven turbines.

The adoption of all-geared turbines on two shafts in these destroyers permitted an increase in the propeller efficiency of about 12 per cent., and an additional improvement in the steam consumption of the turbines, of about 10 per cent. at full power, and about 30 per cent. at one-tenth of full power, also a slight saving in the total

* Paper read before Section G of the British Association at Bournemouth.

weight of the machinery, as compared with a twin screw arrangement of direct-driving turbines hitherto adopted in these vessels.

During the war gearing was universally adopted for light cruisers, battleships and battle cruisers of the highest powers, and during the last four years practically no direct-driven turbines have been fitted. Vessels are now in service with installations of geared turbines of 100,000 h.p., and the horse-power transmitted through a single gear wheel has reached 25,000, and the power through a single pinion 15,500.

The further adoption of geared turbines in the mercantile marine was considerably retarded during the war. When the question of type of machinery came under discussion for the standard ships, preference was given to reciprocating engines owing to the fact that all the usual builders of marine turbines were full of orders, and were required to give preference to the manufacture of turbines for war vessels, which limited the number of turbine engines which could be built for commercial vessels, and also to the fact that the country had great resources at its disposal for the quick manufacture of ordinary triple-expansion engines. In the later standard ships of the fabricated type, however, geared turbines were adopted.

At the present time the total horse-power of geared turbines for vessels for commercial purposes completed and under construction is about 1,400,000; and the total horse-power of geared turbines for war and commercial purposes completed and under construction is about 18,000,000. Previous to the adoption of geared turbines the total horse-power of direct-driven turbines was 16,500,000, making a total horse-power of marine turbines fitted into vessels and under construction of about 34,500,000.

The curve shown on Plate I represents: (A) The output at the end of each year in shaft horse-power with direct-driven turbines; (B) with geared turbines.

In the initial stages of the development of gearing certain factors required to be considered in order to ensure certainty of success with the gears for marine work. Perhaps the most important of these was the behaviour of the gearing in a heavy sea-way. No data was available as to the life of gears under seagoing conditions, and very liberal allowances were made with regard to tooth pressures. The experience gained, however, as a result of actual running on service, has led to a gradual increase of tooth pressures.

One of the chief objections advanced against gearing was the anticipation of noise and with a view to obtaining as silent running as possible fine pitch teeth with an angle of 45 deg. were adopted, the pitch of the tooth being $\frac{7}{16}$ in. In later designs, and with improved methods of cutting, the spiral angle has been reduced to 30 deg. The reduction of the spiral angle from 45 deg. to 30 deg. permits of considerable increase of tooth pressure without reduction of the margin of safety.

Careful investigations which have been made as to the causes of noise have shown the noise to be due to slight inaccuracies in the pitch of the teeth. An improved method of cutting gear wheels and pinions so as to obtain a higher degree of accuracy was developed, and described in a paper by Sir Charles Parsons before the Institution of Naval Architects in 1913. The "creeping" mechanism adopted is additional to the machine used in the usual hobbing process, and its action is such as to distribute any errors that may be in the machine uniformly around the wheel instead of leaving such errors, as would be the case in a machine not fitted with "creeping" mechanism, to occur at definite angular positions on the wheel. Incidentally, the errors are also at the same time reduced, resulting in quieter running gears being obtained. The horse-power of gears cut by machines fitted with the "creeping" tables represents about 75 per cent. of the total in use.

Within the last three or four years a further development has taken place in the case of mercantile vessels by the adoption of double-reduction gearing instead of single-reduction gearing, which had previously been the practice.

Double reduction gearing permits of larger ratios between the revolutions of turbine and propellers being obtained without excessive size of gear wheel, so that even in very slow-speed vessels the turbines may be designed to run at the speed for maximum economy. The increased efficiency obtainable with a double reduction scheme and higher speed turbines as compared with turbines and single reduction gears is in some cases as much as 7 per cent.

From first to last a considerable advance has been made in the efficiency of the steam turbine. In 1892 a turbine of 100-kw. gave a steam consumption of about 27 lb. per kilowatt, whilst later in larger sizes, say of 3,000 kw., a steam consumption of under 15 lb. was obtained. In 1907 there was a further reduction to 13·2 lb. per kilowatt, and at the present time steam consumptions for large land installations as low as 10·3 lb. per kilowatt-hour with 275 lb. steam pressure and 200 deg. of superheat, which is equivalent to about 7·5 lb. per brake horse-power, are being obtained.

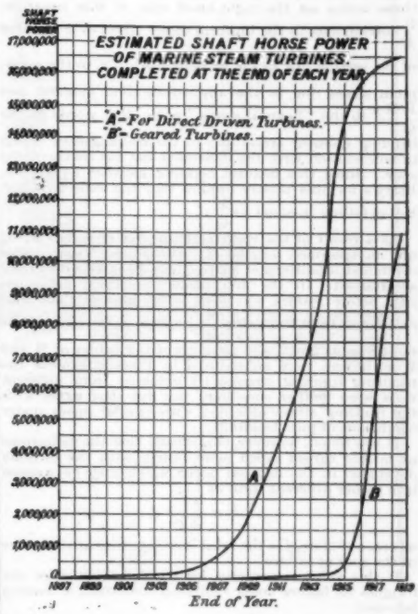
In marine work, for the earlier turbine vessels the steam consumption of the turbines worked out at about 15 lb. to 16 lb. per shaft horse-power, and in later direct-driven turbines under 12 lb. per shaft horse-power was obtained, whereas at the present day, with double reduction gearing and reaction turbines, consumptions of under 10 lb. per shaft horse-power can be obtained with saturated steam, and under 8 lb. per shaft horse-power with a superheat of 200 deg. F. From these figures it will be readily seen that a remarkable advance has been made in increasing the efficiency of the turbine, the steam consumption being about one-half of what it was eighteen or twenty years ago.

TABLE OF COMPARATIVE RESULTS.

*Parsons Single Reduction Geared Turbines and Reciprocating Engines.*

NOTE.—All comparisons are for ships of same sizes and models and same boilers.

| Name of Vessel. | Type of Machinery. | Dimensions and Tonnage. | Approximate Displacement. | Speed in Knots. | Coal Consumption. |
|---|---|---|---|---|---|
| | | | tons. | | tons per day. |
| (1) "Vespasian" | A.—Turbines, single-screw | 275 ft. × 38·75 ft., 2,150 gross | 4,350 | 9½ | 14·17 |
| | B.—Reciprocating, single screw | 275 ft. × 38·75 ft., 2,150 gross | 4,350 | 9½ | 17·07 |
| | (1) Natural draught: Result = 17 per cent. less consumption by turbines. | | | | |
| (2) "Cairnross" | C.—Turbines, single-screw | 369·75 ft. × 50·75 ft., 4,000 gross | 10,000 | 10·15 | 27·816 |
| "Cairngowan" | D.—Reciprocating, single-screw | 369·75 ft. × 50·75 ft. 4,000 gross | 10,000 | 10·15 | 32·692 |
| | (2) Natural draught: Result = 14·93 per cent. less consumption by turbines. | | | | |
| (3) "Mahanada" | E.—Turbines, single-screw | 7,200 gross | 13,500 | 12·138 | 54·8 |
| "Malakuta" | F.—Reciprocating, single-screw | 7,200 gross | 13,500 | 11·533 | 67·44 |
| | (3) Natural draught: Result = 19 per cent. less consumption by turbines. | | | | |
| (4) "Cumberland" | G.—Turbines, twin-screws | 9,500 gross | 15,000 | 13·11 | 77·5 |
| "Devon" | H.—Reciprocating, twin-screws | 9,500 gross | 15,000 | 12·8 | 91·5 |
| | (4) Howden's forced draught: Result = 15·3 per cent. less consumption by turbines. | | | | |


SHAFT HORSE POWER
ESTIMATED SHAFT HORSE POWER OF MARINE STEAM TURBINES. COMPLETED AT THE END OF EACH YEAR.
A-For Direct Driven Turbines.
B-Geared Turbines.
A
B
1907 1909 1911 1913 1915 1917 1919
End of Year.

By the courtesy of several shipowners Table A has been prepared, giving particulars of the performances of vessels with Parsons geared turbines, as compared with sister ships fitted with reciprocating engines.

There are several varieties of turbines now in use, some of them only, however, to a limited extent, but within the scope of the paper it is not possible to make more than a few general remarks.

The various turbines may be classed under the headings "Impulse" and "Reaction," and in some cases a combination of the two. The reaction class has low steam velocities. In modern practice the blades of a reaction turbine are of a reasonable length and the maximum possible efficiency is higher than obtainable with any other type.

The question of maintenance of efficiency and economy in wear and tear under long continued service is a very important one to shipowners. The reaction turbine is the only system which has been tried over a long period of years in mercantile vessels. The result of such experience points to the fact that, with ordinary care, the economy of the reaction turbine is fully maintained after years of running. This maintenance and economy is due to the low steam velocities employed. It has been found that with high steam velocities there is a tendency for the blades to suffer erosion, probably caused by drops of condensed water mingled with the steam, the action increasing rapidly with increase of velocity. Blades which have been eroded show a falling-off in efficiency, but this erosive action is reduced by the adoption of superheated steam.

As regards the life of gearing, there appears as the result of experience to be no reason why it should not have a very long life, provided, of course, that ordinary precautions are taken in the manufacture and cutting of the gears, and that efficient lubrication is provided. In this connection it may be mentioned that the gearing of the Vespasian shows practically no signs of wear. The Cairnross, which was the next vessel to the Vespasian to be fitted with geared turbines, has unfortunately been sunk by enemy action. The Mahanada has now been four and three-quarter years on continual service, and from a report made quite recently the gearing is "in as good a condition as when it first left the builders' works"; from inquiries made from the owners of this vessel, the turbines and gearing during this period have not cost anything for upkeep.

On land, geared turbines have been adopted for certain work in connection with the generating of electricity. In direct-current working before the introduction of gearing, difficulties were met with owing to the fact that dynamo speeds were too low for direct coupling to turbines of maximum efficiency. Owing to the limitation of dynamo design, the turbine speed had in some cases to be reduced to less than half the speed corresponding to maximum efficiency, and in such cases mechanical gearing has been employed with considerable advantage, an economy of 15 per cent. having been effected. In the case of alternators of fair size the speeds are usually such that direct coupled turbines of maximum efficiency can be used.

One of the earliest applications of gearing was that of driving a continuous running plate rolling mill for the Calderbank Steel Works of Messrs. J. Dunlop and Co. This gearing, which was of the double reduction type, and driven by a turbine of 750 h.p., has remained in continuous operation to the present time, and a recent examination showed no signs of wear in the teeth.

Gearing has opened up a new field for the steam turbine in the driving of cotton, jute, paper and other mills.

A number of mills, both in Great Britain and in the Colonies have adopted this method of driving with most satisfactory results, both from the point of view of economy and reliability.

In conclusion, it may be safely said that the introduction of the steam turbine, has added to the progress of the world, since the turbine has considerably cheapened mechanical power on land and sea, and has rendered possible speeds greatly in excess of those obtainable with reciprocating engines. Already it has entirely superseded the reciprocating engine for war vessels and for high speed and modern mercantile vessels, and bids fair in the near future to being applied on an extensive scale for low-speed vessels, in view of the substantial economy in coal consumption obtainable thereby.

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POWDERED COAL FOR SHEET MILL.—According to *Power*, New York, powdered coal is to be used throughout for firing boilers and furnaces in the new sheet mill of the Falcon Steel Company, now being erected at Niles, Ohio. The power-plant boilers will be powdered coal-fired, using the Quigley compressed-air system for transporting and burning the coal. The pulverised coal will be transported from the milling plant through standard 4-in. diameter wrought pipes to furnaces and boilers for various distances aggregating approximately 800 ft., and will be switched from the main distribution line to a storage bin in the power-house, for use as required.

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DETERMINING THE BEARING VALUE OF ALLOYS.—According to the Sub-Committee on bearing metals of the Research Committee of the American Society of Mechanical Engineers, as stated in *Engineering News-Record*, New York, the only mechanical or physical test of a bearing alloy is to find whether the alloy has a sufficiently high factor of safety against distortion or rupture under specified service conditions at service temperature. The members of the sub-committee are convinced that without the application of modern metallography any investigation of this subject is a waste of time. For example, it is entirely due to the dissimilarity of crystals in bronze that it makes a better bearing alloy than brass. The essential characteristic of all bearing alloys is a structure made up of alternately hard and relatively soft microscopic particles intimately mixed. The softer crystals are more readily abraded and therefore wear slightly below the surface of the bearing crystals and thus form slight depressions which serve for the retention of the lubricant. The sub-committee believes that much more can be learned from a study of failures and of old bearings, together with their journals, than from accelerated service tests in laboratories.

## INTERNATIONAL RAILWAY ASSOCIATION.

THE International Railway Congress Association has recently been reconstituted under the title "International Railway Association." The following are a few notes on its origin, work and aim.

It was one of the earliest international scientific societies. The foundations of the association were laid at the Brussels Congress in 1885, convoked by the Belgian Government for the purpose of celebrating the fiftieth anniversary of the Belgian railways. At this first meeting, as well as during the sessions which followed, the delegates dealt exclusively with the study and discussion of a number of technical and administrative questions having as their object the progress of railway science. The initiator and first president of the permanent Commission of the Association, Mr. Fassiaux, had in view, at the beginning, to bring into existence a "Railway Union," after the fashion of the postal and telegraphic unions. But he became gradually convinced that such an end was unattainable, and thereafter devoted himself entirely to the idea of creating a permanent centre for the meeting of periodical scientific congresses. The permanent Commission appointed by the first congress met at Brussels, on February 20, 1886. One of its first concerns was to prepare a series of statistics the final text of which was adopted at the Milan session in 1887. The modifications which were made since are of minor importance. The association is represented by a permanent Commission which it elects, and which has its seat at Brussels. This Commission at the present time consists of past-presidents of the sessions, who are *ex-officio* members, and 45 elected members; its president is Mr. V. Tondelier, presiding director of the Executive Committee of the Belgian State Railways, and its general secretary, Mr. L. Weissenbruch, chief engineer and managing director of the same railways. At the closing sitting of the eighth session (Berne, 1910), when the twenty-fifth anniversary of the foundation of the association was celebrated, it was decided that the ninth session should take place at Berlin in 1915. The preparations for this were far advanced in 1914, when Germany declared war. At the conclusion of hostilities and after the return of the Belgian Government, the association was placed under sequestration, in pursuance of the Belgian law of November 10, 1918, owing to the fact that a portion of its assets belonged to the subjects of enemy nations. The sequestrator having ordered the dissolution and liquidation of the society, the railway administrations, members of the association, belonging to 35 countries, decided to transfer their property to an association established upon exactly the same bases as before, and entitled the "International Railway Association." These countries are: Argentina; Belgium and Colony; Bolivia; Brazil; Chili; China; Costa Rica; Cuba; Denmark; Dominican Republic; Ecuador; Egypt; France, Algeria, Tunis and Colonies; Great Britain and Ireland, India, Protectorates and Colonies; Greece; Haiti; Italy; Japan; Luxemburg; Mexico; Netherlands and Colonies; Nicaragua; Norway; Paraguay; Peru; Portugal and Colonies; Rumania; San Salvador; Serbia; Siam; Spain; Sweden; Switzerland; United States of America; and Uruguay. The statutes of the original association, now dissolved, have not been altered. All that has been done has been to add to them an article, 3A, in the following terms: "The Permanent Commission, by the written vote of a three-quarters' majority of all its members, decides the countries to be included in the association."

As a first manifestation of the resumption of activity on the part of the association, the Executive Committee will recommence shortly the publication of its monthly bulletin. The Permanent Commission, which will be convoked at an early date will be called upon, as a primary duty, to declare itself on the subject of the place and date of the ninth session, at which the statutes in their complete form will be discussed by the plenary assembly with a view to their approval.

Numerous expressions of encouragement have reached the Executive Committee, and the latter has every reason to hope that the "International Railway Association" will continue to pursue with more success than ever the aim which its predecessor assigned to itself, namely, the furtherance of the science and working of railways.

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BLACK SEA PORTS.—A telegram has been received by the Board of Trade from the Rear-Admiral commanding in the Black Sea stating that trade is now open with all Russian Black Sea ports. In the case of Odessa, information has also been received from the Admiralty that Captain Kerr, R.N., will be stationed on shore at Odessa to carry out the duties of a British Consul-General temporarily until a Consular Officer is appointed to the port and arrives at Odessa.

AMERICAN SHIPPING.—According to *The American Marine Engineer*, the Bethlehem Steel Corporation has let the contract for 20 steamers to carry iron ore from the north side of Cuba and the Chilean mines. The ore will be discharged at Philadelphia if the proper facilities are offered at that point. The new steamers will be 11,000 deadweight tons each, and built to suit the requirements of the Panama Canal. Work has already been started on the first vessel at the Fore River Plant, Quincey, Mass. The Standard Oil Company has contracted for six tank steamers of 12,000 tons capacity each. These tankers may be built at Sparrows Point, Maryland, but this is not definite. They are to be used for Pacific as well as Atlantic trade, the intention being to send at least four of the new vessels to develop the oil-carrying trade to China, Japan and to other ports in the Far East.

## METAL CONSTRUCTION OF AIRCRAFT.

TO THE EDITOR OF ENGINEERING.

SIR,—In reply to the comments in a letter in your issue of August 22, page 254, referring to stresses in "Duralumin" aeroplane spars, dealt with in my paper on the "Metal Construction of Aircraft," I may say that the method of calculating the stresses explained was purely an empirical one based on the results obtained from tests carried out on a very large number of actual spar lengths under combined conditions of loading.

If P is the endlong load, and M the maximum applied bending moment on a girder of cross-sectional area A and the moment of inertia I, then according to Perry's formula

$$f = \frac{M\,y}{I}\left(\frac{Q}{Q-P}\right) + \frac{P}{A}$$

Where $f$ is the limiting stress and Q is the equivalent endlong crippling load as calculated by Euler's formula. Since for the particular proportions of spar used in certain aeroplane practice Q is very large compared with P, the value of the fraction $\frac{Q}{Q-P}$ will not be greatly altered by adding P to the top and bottom. Then the above equation may be written

$$f = \frac{P}{A} + \frac{M\,y}{I} + \frac{P}{Q}\,\frac{M\,y}{I}$$

without any sensible error. Now if one considers the three terms on the right-hand side of this equation, $\frac{P}{A}$ corresponds to the uniform direct stress over the area of the section due to the endlong load, $\frac{M\,y}{I}$ to the maximum stress due to the applied bending moment and $\frac{P}{Q}\,\frac{M\,y}{I}$ to the "flexural stress" or in other words to the bending moment stress due to the endlong load acting in conjunction with the deflection $\delta$ at the centre of the spar. Since this flexural bending moment equals $P\delta$, Perry's formula tacitly implies that the deflection just before failure is equal to $\frac{M}{Q}$.

As a result of the very large number of tests carried out on specimen lengths of "Duralumin" spar under combined conditions of loading, two facts were definitely ascertained. In the first place the actual deflection just before failure was very much greater than that calculated from the value $\frac{M}{Q}$, in some cases as much as ten times as great, and secondly if the values of M and P at failure were substituted in Perry's formula the resulting limiting stresses ($f$) obtained from different tests were neither consistent nor did they agree with the limiting stress obtained with similar spars under conditions of pure bending.

It was found, however, empirically that the deflections at failure agreed much more nearly with the formula developed in the original paper which may be written in a rather different form as

$$\delta = \frac{f\,I}{Q\,y}$$

where, as before, $f$ is the total limiting stress at the centre of the spar at failure.

If this value is assumed for the deflection, then the formula for failure under combined conditions of loading becomes

$$f = \frac{P}{A} + \frac{M\,y}{I} + \frac{P\,f\,I}{Q\,y}\cdot\frac{y}{I} \text{ or } f\left(1 - \frac{P}{Q}\right) = \frac{M\,y}{I} + \frac{P}{A}$$

which in its most useful form reduces to

$$f = \left(\frac{M\,y}{I} + \frac{P}{A}\right)\left(\frac{Q}{Q-P}\right)$$

This formula, which is due to Mr. J. E. Temple, of Messrs. Vickers, Limited, Barrow, should be compared with the original Perry formula.

It was found that the limiting stresses calculated by means of this formula from the observed values of M and P at failure, agreed very well with the limiting stress for spars of similar section tested under conditions of pure bending.

One point of interest may be mentioned. If M the applied bending moment is put equal to zero in Perry's formula, it is seen that P, which then becomes the crippling load on a similar spar tested as a strut under ordinary conditions of endlong loading, is equal either to $f$A or to Q. In other words, the mathematical basis on which the Perry formula is derived is that the crippling load for a simple strut is constant up to a certain critical value of $\frac{I}{K}$ and above this is equal to the crippling load calculated by Euler's formula. This is, of course, well known.

Now if M is put equal to zero in Temple's formula we get

$$\frac{1}{P} = \frac{1}{Q} + \frac{1}{f\,A}$$

for the equivalent simple strut formula which can be at once reduced to

$$P = \frac{A\,f}{1 + C\,\frac{l^2}{K^2}}$$

which is the Rankine Gordon strut formula. The difference between the new formula and Perry's formula is exactly similar to that between the Rankine-Gordon strut formula and the ordinary mathematical Euler assumption.

The above notes, when read in conjunction with the original paper, should clear up the points raised in this connection by your correspondent.

With reference to the figure given in the original paper for the value of Young's modulus for "Duralumin." The correct figure for "Duralumin" bar and tube is 4,700 tons per sq. inch. In dealing with built-up girders of the type used for aeroplane spars and airship structures, the main members are stiffened somewhat owing to the fact that the bracing pieces are riveted at intervals to the main members. In order to allow for this effect a figure found as a result of direct experiment is used for the equivalent value of Young's modulus, namely, 5,500 tons per sq. in., the cross-sectional area of the bracing pieces being in this case ignored in calculating deflections.

Yours faithfully,
A. B. THURSTON.

Cologne, B.E.F., September 13, 1919.

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## UNIVERSITY MATHEMATICS FOR ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—I would like to reply to Mr. Dunton's criticism of my letter of August 31, which appeared in your issue of September 5.

I have re-read his letter of August 15 and find that he nowhere specifically states that he is referring to the hyperbola and circle of unit radius. In his second and fourth paragraphs he quotes this Hyperbola for the purpose of working out his result, but he draws no particular attention to the fact that it is the Hyperbola of unit radius, and most certainly does not state that the result he obtains is only applicable to that particular case.

I stated that his result was misleading and I reiterate that statement. For by the same reasoning one could obtain the result that the V in sin V is equal to twice the corresponding circular sector, because area of circular sector $= \frac{1}{2} r^2 V$, and when $r = 1$ this is area $= \frac{1}{2} V$, *i.e.*, V = twice area. I must confess that I have not come across this meaning of V yet, but it is quite as justifiable as Mr. Dunton's assertion that the V in sinh V = ½ the area of the Hyperbolic sector.

Mr. Dunton says:—"There was no call for me to consider any other Hyperbola, this being the only one in the piece of erroneous teaching that I was rectifying." He does not even infer that this is the Hyperbola referred to in the teaching mentioned; in fact, he gives no reason for the choice of this particular case, and it is by no means obvious that the special result obtained is due to this choice. In this respect I think he is more likely to mislead students than to teach them.

In the first paragraph of Mr. Dunton's letter of the 8th inst. he says:—"But this is because he omits to mention my perfectly clear statement that I was referring to the circle of unit radius and the hyperbola that corresponds to that circle."

In the fourth paragraph of my letter I state:—"Your correspondent has chosen a particular case for his illustration of the hyperbola and has thus obtained a result which is somewhat misleading"; and, again, in the ninth I say:—"Of course, when $n$ and $a$ are each unity, as in the examples chosen by your correspondent," so whose quotations are more careless?

My point was, and is, that by choosing a special case Mr. Dunton obtained a result which, whilst correct in itself, would be most misleading if applied generally, and I showed that the general result was something quite different.

Mr. Dunton has argued from the particular to the general.

In the last paragraph of his letter of August 15 he says:—"We thus arrive at the conclusion that the V in any hyperbolic function, such as Sinh V, is numerically equal to twice the area of the corresponding hyperbolic sector." This is a perfectly general statement, notwithstanding that a particular case may have been taken to illustrate it, and there is nothing to show that only the hyperbola of unit radius is referred to. I may confess that it took me some little time to discover where the fallacy lay. It amounts to saying that because when $x = 1$, $x^n = x$, then $x^n = x$ in general.

With regard to his remarks anent my quotation from Edser, if he can prove it to be wrong, I should be very pleased to learn in what particular; but if he cannot do so, I think he should at least withdraw that remark.

Mr. Dunton makes a very sweeping reference to British Universities. I am afraid my academical attainments and knowledge of the matter are too poor to offer an opinion on that matter; but, judging from his attempt to rectify the teaching of London University on Mathematics, I would not be inclined to give much weight to it, and I think the "cloven hoof" is to be discerned in the last paragraph of his letter of the 8th inst.

With regard to the letter of your correspondent, "A. R. L.," in your issue of the 12th inst., whilst Function Theory is undoubtedly the main highway of mathematical progress, geometrical illustration and analogy are most important auxiliaries, and for many students clothe with flesh what would otherwise be but very dry skeletons of mathematical knowledge.

Yours faithfully,
WM. HUGHES.

50, Bellevue-road, Southampton,
September 15, 1919.

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PERSONAL.—We learn that the name of the British Westinghouse Electric and Manufacturing Company, Limited, has been changed to that of "Metropolitan-Vickers Electrical Company, Limited." The certificate of the Registrar of Joint Stock Companies bears the date September 8, 1919.

# THE PARAVANE.*

By ROBERT F. MCKAY, M.Sc.; A.M.Inst.C.E.; A.M.I.Mech.E.

*Introduction.*—As in the case of most inventions, the paravane has only been brought to its present state of perfection after some years of experimental work. Originally devised and developed by Acting Commander Burney as a weapon for attacking submerged submarines, it has also been successfully applied by him as a method of protecting vessels against mines, and as a method of cutting up hostile mine-fields by high speed vessels.

Throughout the war every effort was made to prevent the details of this invention from leaking through to the enemy. Even the word "Paravane" itself was only used in confidential documents, and the secrets of the device were strictly limited to those who were concerned in its manufacture or development. In the case of the installation for merchant shipping when the same strict control could not be exercised as in the Service, the word "Otter" was used to designate the device. Whilst it is not claimed that the secrets of the invention were unknown to the Germans at the time of the signing of the Armistice, it is at least certain that the enemy had not developed and perfected any methods of preventing its continued successful use. In this paper it is desired to lift, as far as is yet possible, the veil of secrecy imposed by the war on the construction and utility of the paravane.

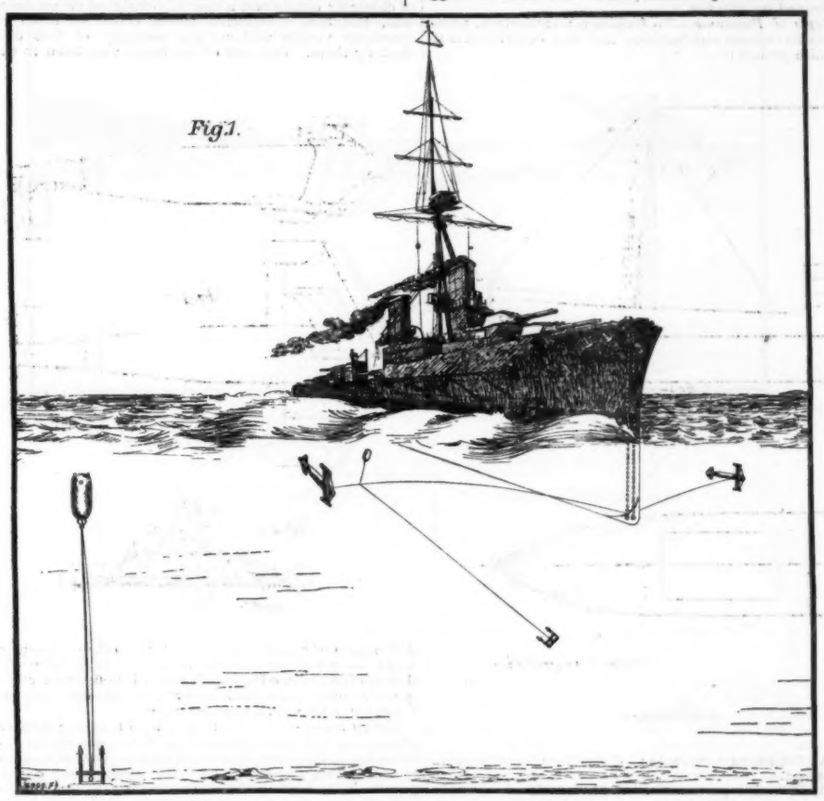


*Fig.1.*

*Development of Explosive Paravane.*—It can now be seen that considering the developments in submarine construction and tactics that have taken place, the problem of combating submarines when deeply submerged had not been very seriously attacked previously to the war. Under peace conditions, submarines rarely, if ever, dived much below the depth required to allow deep draught vessels to pass over them without fouling. Accordingly about 50 ft. was the maximum depth at which a hostile submarine was considered likely to operate. The only device for attacking submarines in pre-war days was that known in the Service as the "Modified Sweep." As this merely consisted of a line of charges towed directly astern, not only was the area swept per vessel small, but the depth reached by the explosive charge was only about 40 ft. The obvious defence of an attacked submarine lay in diving, and as the war progressed the depths to which submarines could attain increased until towards the latter part of 1918, they could safely remain at depths of nearly 200 ft.

Commander Burney realised that the development of the direct attack on submerged submarines lay, therefore, in two directions, first to increase the dangerous area swept by the explosive charges towed by a vessel, and secondly to increase the depth at which those charges could be towed. Various experiments were carried out to see what was the largest area which could be swept out by a vessel using some form of sweeping apparatus. It was soon found impossible to tow any form of net at right angles to the course of the ship owing to the great resistance of the water at even moderate speeds. It was accordingly decided to develop a form of "Rake," on the principle of a hay-rake. If a rake could be devised whose prongs would penetrate to a considerable depth and be sufficiently close together to foul any submarine on its path, it is clear that a form of apparatus is obtained which would sweep out a considerable area.

In the early experiments a form of rake was devised which had four prongs, and which covered a total width of 180 yards. Two charges were towed directly over the stern of the ship at an angle of 45 deg., and two further charges were towed on each beam of the vessel, and kept in place by what was termed a surface torpedo. A modern destroyer, H.M.S. Mastiff, was fitted with this device in the middle of 1915, and was attached to Sir R. Y. Tyrwhitt's flotilla at Harwich. The principle of the device was reported upon favourably by Admiral Tyrwhitt, but owing to the considerable weight and complication of the gear, certain modifications soon suggested themselves. After further experimental work the outside charges were eliminated, and the sweep contained only the two charges towed from the stern of the vessel.

The explosive paravane as it was finally developed, is a torpedo-shaped body carrying near its head a large steel plane, and near its tail horizontal and vertical fins. The plane is set at a small angle to the centre line of the paravane, and is in an approximately vertical position when the paravane is being towed. The thrust of the water on the plane when the vessel is in motion, carries the paravane away from the fore and aft centre line of the vessel. In this way a spread of sweep, i.e. distance from paravane to paravane, of about 200 ft. may be obtained. The stability of the paravane is increased by the horizontal and vertical fins at the tail. Depth-keeping mechanism is also fitted in the tail of the paravane. This consists of a horizontal rudder actuated by a hydrostatic valve, i.e. a valve which is operated by difference in water pressure due to any change in depth. When the paravane is launched the rudder makes it go down to a pre-determined depth, and if the paravane moves from that depth, the rudder is brought into action and tends to keep it on a steady course.

*Features of Explosive Paravane.*—There are several ingenious features of the explosive paravane installation. The paravane not only carries a heavy charge of T.N.T., but also the firing gear, a depth-recording device, &c., whilst elaborate safe-guards are fitted to render the paravane safe when being handled. The explosive charge can be detonated in one of three ways by an electric current which passes through a core in the towing wire. These are: (1) by impact; (2) by an excessive load coming on the towing wire; and (3) by hand, and are to meet various contingencies that might arise. For example, the paravane might strike the hull of the submarine, either a direct hit, or through the towing wire fouling the hull and slipping over its surface until impact between submarine and paravane occurs. Striking gear on the nose of the paravane then operates a switch which makes the necessary contact to detonate the charge. If, as might easily happen, the towing wire becomes entangled in the external fittings of the submarine, the method of detonating the charge by impact is not operative as the paravane will not strike the submarine. In this case, however, an additional load comes upon the towing-wire. A special dynamometer is fitted so that any load above one pre-determined trips another switch which again makes the necessary contact to detonate the charge. The third alternative for detonating the charge is by a hand switch on the bridge of the attacking vessel. The charge can then be detonated at will at any spot where a submarine may be presumed to lie from the presence of surface oil or wreckage.

Special arrangements are made to render the paravanes safe when being handled. The detonators are inserted into, and kept in position within, the primer by a mechanism operated by a hydrostatic valve. This valve is set to move when the head of water is 20 ft. In addition, three separate safety devices are provided in the firing circuit. The crew and vessel are thus safeguarded from the effects of accidental firing whilst the paravanes are on the deck or in the sea near the vessel.

On account of the wear and tear on the towing-wires, &c., it is not practicable to tow the sweep constantly, and special attention was devoted to the problem of dropping the paravanes quickly. If a submarine were sighted at some distance from an attacking vessel, it is clearly desirable to get near the spot in the minimum time. If the vessel had to stop in order to drop the sweep, valuable time would be lost, and the chances of success jeopardised. Special dropping davits, rendering winches, &c., were, therefore, designed in order to facilitate the dropping of the paravanes at any speed up to 20 knots. With a well-trained crew it was possible to be towing the paravanes at a depth ready to fire within a minute of the time that the order was given to drop the sweep. The cost, weight and complexity of the apparatus militated against its universal fitting in trawlers, drifters, merchant vessels and the like, and it was only in regular Navy vessels with well-trained crews that its operations could be undertaken. The device was, however, fitted to a large number of British and Allied destroyers.

*Results obtained by Explosive Paravane.*—It will be realised that the two towing-wires and explosive paravanes form a dangerous weapon when travelling through the water at high speed, and considering the nature of the problem, its success in attacking submerged hostile submarines is remarkable.

In considering the results obtained by this weapon it must be remembered that the paravanes were not operating against the submarines on the surface when they are most vulnerable, but were attacking them under water where they are very difficult to locate and destroy. Attacks by paravanes were only undertaken when other forms of attack, save possibly by depth charges, were not practicable. The significance of the paravane success, therefore, does not so much lie in relation to the total number of submarines known to have been destroyed, but in the fact that the paravane achieved success when other methods of attack could not be attempted. It is interesting in this connection to compare the form of attack by paravanes with that by depth charges, as these were the only two successful methods of direct attack on submerged submarines developed during the war.

A depth charge, of which there are now a considerable number of different types, contains its own firing gear, and can be set to explode at any given depth. When once released, however, the firing of the charge is automatic, and cannot be controlled from the vessel. In an attack by depth charges, therefore, it is necessary to drop a large number in order to cover the area within which the submerged submarines may lie, and it is possible that even after the expenditure of a very large number, the submarine may escape undamaged.

Paravanes, however, can be towed steadily until impact occurs, and need only be fired by hand if there is sure indication that a submarine is in its immediate neighbourhood. It will be seen, therefore, that an attack by paravanes has substantial advantages over that by depth charges. In comparing the results achieved by paravanes and depth charges, it must be borne in mind that at least twenty times as many vessels were fitted with this latter weapon, although the "known sunk" results were only four times as great. Hence in comparison to the number of vessels fitted, the explosive paravane obtained by far the higher proportion of successes.

Because attacks occurred when the submarines were submerged, it is also impossible to give any exact results obtained by the device. But of 53 attacks made, some success was registered on 21 occasions. In five of these there has been incontestable proof that the submarine was sunk; but it will never be known in how many other cases the explosive paravane may have been the means of inflicting such damage upon the submarine as to prevent them from returning to their base.

It is difficult to assess in financial terms the value of the paravane installation to the nation, and to estimate the destructive potentialities of the submarines which have been sunk by its means. Some submarines are known to have sunk shipping and cargoes to the value of many millions of pounds, and any estimate of the shipping saved by the destruction of any one submarine must be quite hypothetical. It is computed, however, that the total loss in shipping due to the submarine warfare is about 1,000,000,000*l.* Hence working only on the certainties, each submarine destroyed

* Paper read before Section G of the British Association at Bournemouth, September 13, 1919.

was responsible for about 5,000,000*l.* worth of damage. Accepting this figure as a basis, it may be said that the explosive paravanes saved further damage being inflicted upon our shipping to the extent of about 25,000,000*l.*

*Development of Protector Paravane.*—It had become obvious at an early date that with slight modifications the explosive pravanes could be adapted for the protection of vessels against moored mines. To do so, it was necessary to remove the point of tow from the stern to the bow of the towing vessel, and structurally to replace the explosive charge, firing-gear, &c., by some form of cutting apparatus on the head of the paravanes. As soon, therefore, as the submarine sweep was developed to a stage which justified its manufacture and fitting on a large scale, Commander Burney was directed by his commanding officer, Captain F. L. Field, R.N., now Rear-Admiral Field, the present Director of Torpedoes and Mining, to concentrate upon a paravane which would prove an effective form of mine protection. This was done, and with the help of a numerous and able staff, different forms of mine protection were evolved.

At the beginning of the war it was fully expected that the enemy would lay mines defensively to protect harbours, estuaries, and a retreating fleet, or offensively to destroy or damage our warships when on recognised courses in the open sea, but when they began the unrestricted use of mines in order to destroy the Allied mercantile shipping, the Allies were placed at a serious disadvantage. Mines were not always laid in the form of a mine-field, but often singly, so that the finding of one mine, perhaps by a disaster to the vessel concerned, did not necessarily imply that there were others in the immediate neighbourhood. Submarines were adapted as mine-layers, so that the radius within which mines were likely to be found was considerably increased. Fortunately as mines cannot be moored in depths greater than 40 to 50 fathoms, and are, in fact, seldom laid in depths greater than about 30 fathoms, the area within which mines could be laid is somewhat restricted. But even with this restriction the boats available for mine-sweeping were inadequate to cope with the problem. It must be remembered in addition that mine-sweeping, even under the best of conditions is a dangerous and tedious operation.

It became apparent that the problem of adequately sweeping for mines would be eased considerably by ensuring that each ship was effectively protected against them. The application of the paravane as a form of protection for ships against moored mines has proved remarkably successful.

Although the special feature of the protector installation is the paravane, the vessel is really protected from moored mines by the wires which tow the paravanes. Two paravanes are towed, one on either side of the vessel by specially manufactured wires from a point on the ship as far forward as possible, and on the line of the keel produced, as shown in Fig. 1. It is essential that these wires should sweep over a wide track before the vessel in order to foul the mooring wires of any anchored mines which lie on or near its course. That this might be done effectively, the wires must move in a horizontal plane at or slightly below the line of keel of the vessel. The inboard end of the wire is, therefore, attached to the vessel as far forward and as low down as possible. This necessitates some special form of fitting at the bow which will be described later. The outboard end of the wire is kept in position by the paravane, which must, therefore, keep at a depth determined by the vessel to which it is fitted, and at as great a distance as possible from the fore and aft centre-line of the vessel. Whilst the paravanes are being towed, the towing-wires form a wedge-shaped protective element advancing before the ship, the "spread" of the paravanes, i.e. the distance from paravane to paravane being about 200 ft. Fig. 2 shows the elevation and Fig. 3 the plan of the protector-gear fitted to a merchant ship, the "wedge" being clearly shown in the plan view.

The action of the protector-gear is simple. The paravane towing-wires foul the mooring-wire of any mine which might strike the vessel, but misses any mine which is too deeply anchored. The speed of the vessel causes the mine and its sinker to be deflected down the "wedge" and away from the vessel until the mine mooring-wire reaches the paravane. On the head of the paravane and forming part of the towing bracket are jaws which carry some specially designed stationary cutter blades. The mine mooring-wire, passing into these cutter jaws, is speedily severed; the sinker drops to the bottom of the sea, whilst the mine floats to the surface well clear of the ship, where it can be seen and destroyed by rifle fire.

*Types of Paravanes.*—To facilitate manufacture, paravanes have been standardised, and may be divided into definite groups:—

(A) Explosive paravanes: These have already been described.

(B) Protector paravanes: (1) Mercantile vessel type. These are generally known as otters; (2) Cruiser and fast liner type; (3) Battleship type.

(C) Mine-sweeping paravanes: These are of the cruiser type but are towed from the stern of a vessel.

(D) Special paravanes.

All paravanes are similar in external appearance, though different in size and details. The type known as Otters, being handled largely by unskilled crews and being fitted to relatively slow ships (whose speed does not exceed 16 knots) are very simple in construction, and cheap to manufacture. The other protector paravanes being for high speed vessels, contain more internal mechanism than the otters, but it is not proposed to describe in detail the differences. Typical illustrations of a paravane are given in Figs. 4, 5 and 6.

*Provision of Tow-Point Attachment.*—There are several problems connected with the paravane installation which merit closer consideration. One of the earliest difficulties that had to be overcome in the fitting-up of vessels was the adequate provision of the tow-point attachment on the fore part of the vessel. On account of the variations in the shape of the bows of war vessels and merchant ships, many different devices were adopted, and in fact the differences were such that every ship had to be considered separately to determine the best method of obtaining the correct tow-point. The various factors that had to be taken into consideration were:—

(1) The tow-point must be as far forward and as low down as possible on the ship.

(2) To enable the paravanes to be hauled inboard on war vessels and to facilitate the docking of merchant vessels, the inboard end of the towing-wire must be recoverable from the deck.

(3) Any special apparatus must not impede the operations of dropping or weighing the anchor at any time, and in the case of war vessels, must not interfere with gun-fire when in a stowed position.

(4) The labour requisite to manipulate the gear must be a minimum, especially on merchant vessels.

To enable the towing-point to be arranged in its correct position, warships and most large liners had a special fitting built upon the fore-foot. Chains were then led from stoppers on the forecastle through suitable fairleads down to and through holes in this stem extension. A swivelling eye in the chain formed the point of attachment for the towing-wire, and by hauling or veering on the two ends of the chain on deck, this eye could be lowered to its working position or it could be raised to the deck level. Necessarily one of these chains is required for each paravane.

In the case of merchant vessels which had very little cutaway at the bow, a sliding shoe was fitted over the bow which could be lowered into position and which carried the ship end of the towing-wire. This necessitated building up a small stem extension. This could be built up without difficulty on new vessels, but for ships already in service necessitated dry-docking. Owing to the damage inflicted by the U-boats, and the necessity of maintaining the Navy and its supplementary boats in seaworthy condition, dry-dock accommodation became increasingly difficult to secure as the war progressed. Under the stress of changing conditions, a specially-designed swivel-boom was, therefore, introduced which could be fitted to merchant vessels without the necessity of first dry-docking them. One end of the boom was fitted to the ship above the water-line whilst the other extremity could be raised or lowered at will. Eventually the sliding shoe became the standardised bow fitting for low speed vessels with a small cutaway at the bow and the boom for those with a large cutaway.

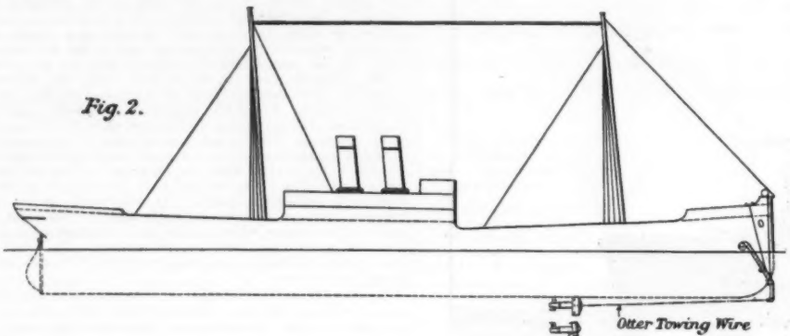



Fig. 2.

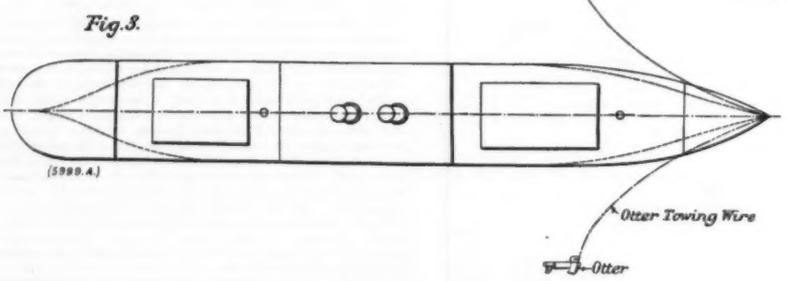



Fig. 3.

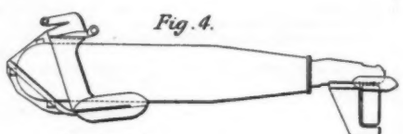


Fig. 4.

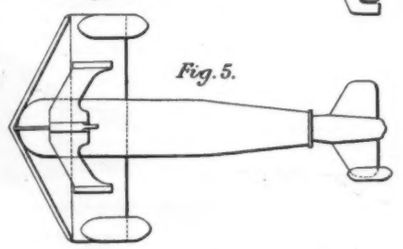


Fig. 5.

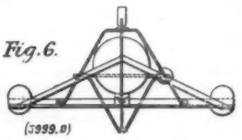



Fig. 6.

*Cutting Device.*—In order to deal with the mine menace effectively, it is not sufficient that a mine should be deflected from the course of a vessel; it must also be brought to the surface and destroyed. The arrangement on the paravane for cutting the mine mooring is very simple but effective, and many experiments were carried out before the final arrangement was standardised. The advantages claimed for the cutter are that it is automatic in action, it has no moving parts, and it is always ready for service. Its efficacy may be judged from the fact that it is found to cut a 1½ in. wire rope with a pull of about 7 cwt., and will, indeed, sever a mine mooring under the static weight of the mine sinker alone. Many cases have been known where mines have been cut by a paravane in rapid succession. The blades are made of "Triumph Superb" steel specially hardened, and can be removed and replaced very quickly if necessary. It is claimed that one of the types of paravanes can successfully sever the heaviest practicable chain or wire rope that can be used to anchor any type of mine.

*Oscillation of Paravanes.*—One of the earliest difficulties that arose in connection with the running of paravanes was their oscillation. Before passing into service, each paravane had to pass certain specified tests when towed under service conditions. One of the chief causes of failure was the oscillation of the paravane, i.e., the paravane instead of running at a constant depth below sea level had an oscillatory motion above and below its set depth. Excessive oscillation of the paravane might clearly prove dangerous to the ship. On the one hand, if the paravane were to come above its set depth it might allow a mine to pass beneath the towing-wire and yet strike the vessel; on the other hand, if the paravane were to dive below its set depth, it might hit the sea bottom, be put out of action, and so leave the ship unprotected. Oscillation has many contributory causes, and necessitates careful design of the otter—correct point of tow, exact balance, correct area of tail fins and rudder, &c. These several particulars were determined by experiment, and checked by theory, and the manufacture of the paravane components thereafter standardised. It has been proved that the chief reasons for oscillation in the

paravane were inaccuracies of manufacture and assembly, and also excessive friction in the rudder-working mechanism. It was, therefore, found desirable to maintain a large staff of competent inspectors at the works of the various manufacturers, and strictly enforce the specification of manufacture which had been drawn up.

*Effect on Speed of Vessel.*—A certain amount of care must be exercised in handling paravanes during launching or when hauling inboard, but various devices have been added to the installation to minimise the labour involved and render it as far as possible fool-proof. When towing paravanes on large ships, it is desirable to manœuvre with as small a helm as practicable in mined areas. When large vessels are turning under full helm, the stern swings round in a circle greater than that covered by the outer paravane. It is conceivable, therefore, that under such conditions a mine might lie outside the spread of the sweep, and yet hit the stern of the vessel. It was at one time proposed to tow two pairs of the paravanes on large ships, the second pair being towed from about amidships in order to protect the ship completely. Events have justified the decision to abandon the second pair, as they have not been found necessary. It is found that paravanes will remain in their correct position relative to the ship both when turning, and over a wide variation in speed.

The reduction in speed when towing paravanes is not serious, except for high-speed vessels. In merchant ships the reduction in speed varies from half to one knot, according to the size of the ship. Trials at higher speeds give the following shaft horse-power absorbed by the paravane installation, when the paravanes are towed by the normal length of 56 yards of wire :—

| Speed in knots. | Horse-power absorbed. |
|---|---|
| 18 | 620 |
| 20 | 850 |
| 22 | 1,100 |
| 24 | 1,420 |
| 26 | 1,780 |
| 28 | 2,230 |

It should be noted that the above figures are deduced from actual tests on the measured mile.

*Design of Towing Wire.*—The design of a suitable towing-wire was a further important study on which considerable research was spent. There are four chief requirements of the wire rope. It must have :—

(1) Adequate strength to carry the load.
(2) Suitable structure to withstand fatigue.
(3) Suitable section to minimise towing resistance.
(4) Sufficient pliability for convenience in handling.

After long and systematic research, three-strand wire ropes were adopted as standard for the protector installation. Each strand consisted of 37 galvanised steel wires of 0·049 in. diameter whose ultimate breaking strength was between 100 tons and 120 tons per square inch. These wires possess the necessary flexibility, and combine the essential requirements of the paravane towing-wires.

The question of fatigue is important. Being subject to a heavy load, the motion of the wire through the water causes vibration which is plainly visible when the wires are towed from a point above water. This is, of course, to be expected, and is analogous to the vibration of telephone wires in air. It is very important that no particular point of the towing-wire should come into contact with anything of a rigid nature, as fatigue would rapidly develop from such a point. Special attention was, therefore, paid to the towing anchorages on paravane and ship. These were arranged so that the rope was fixed longitudinally, but could have a partial transverse movement, and proved very satisfactory in practice.

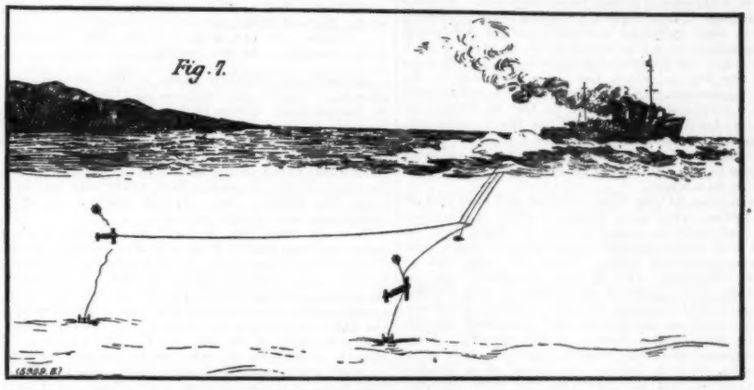
A further interesting feature which might be pointed out is the turning effect of the water resistance on the towing-wires. This can be plainly seen when otters are being towed from a point on deck. It will be pointed out presently on the cinematograph that when otters are being towed on port and starboard quarters at the same depth, the lead of the wire from deck is quite different. Much more wire is visible between deck and sea on the starboard side than on the port side. There is not time to discuss fully this phenomenon. Suffice it to say that this effect is due to the use of a rope of right-hand lay. The turning effect of the water resistance causes the port wire to sag, and the starboard wire to hog. However, as there were no ill effects from the hog or sag of the rope, it was not necessary to have the inconvenient practical arrangement of supplying ropes of different lay for port and starboard paravanes.

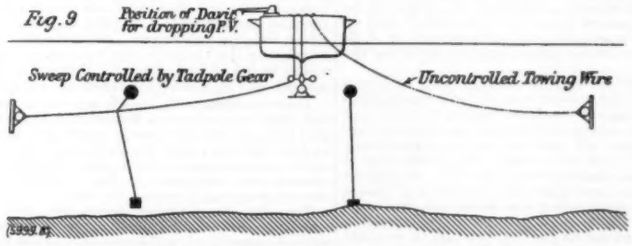
*The Otter Installation on Merchant Ships.*—The organisation necessary to carry out the installation of paravanes was very great. That part of the work relating to merchant shipping was undertaken by Messrs. Vickers, Limited, who put the whole of their vast resources behind the scheme, and carried out the work most effectively. In this connection it has already been noted that paravanes when fitted to merchant ships were called "Otters." The work of the Otter department at Vickers House, London, may be judged from the fact that, although the department was only started in the beginning of 1917, its work became increasingly urgent, until within a very short time it had a trained expert staff in all the important ports of the United Kingdom and of the Mediterranean, large and well-equipped testing stations at Weymouth and Milford Haven, and a staff of inspectors in most of the manufacturing centres of Great Britain. In addition, there was an Otter Commission in the United States, looking after the British interests there, and advising the United States Government on the technical questions involved in the use of the protector gear. Altogether, about 17,000 Otters were manufactured, tested and passed for service, over 3,000 merchant ships were fitted with the installation, and over 7,000 repairs effected. There will be presently shown on the screen a cinematograph film showing various episodes in the manufacture, testing and working of Otters. Permission to show the film has been very kindly given by the directors of Messrs. Vickers, Limited.

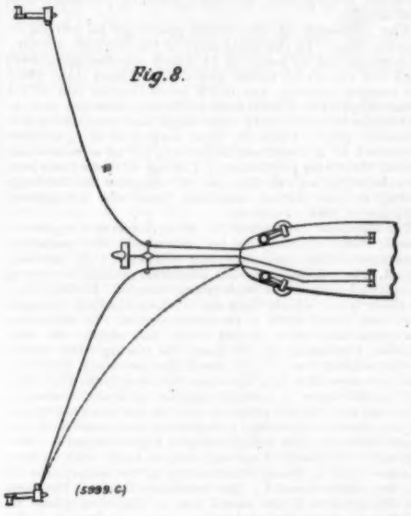
*Results Obtained by Paravanes on Warships.*—The action of the British Admiralty in universally fitting the paravane to suitable craft is sufficient to prove that they considered that the time and money spent on the development of the paravane has been fully justified. Consider first the results achieved by the protector installation on warships. From reports received by the Admiralty, there is evidence that 52 mines have been cut by naval vessels.

In 48 of these cases there is positive proof that the mine has been cut. In the remaining four, the evidence is not absolutely final, but probably so. There are several other cases on record in which mines may have been cut, but as these are classified "doubtful," they are not given in the above table. In addition, it must be remembered that there was no device fitted on British ships to give an alarm when a mine or other obstruction was encountered by a paravane. It is quite possible, therefore, that other mines, not recorded, were cut at night or in a heavy seaway. Working on the assured knowledge of 48 mines cut, there cannot be any doubt about the success of the gear, no matter from what standpoint it is considered. There were about 180 British warships fitted with the installation, so that the proportion of ships saved to ships fitted is high. Assuming that the value of warship tonnage is placed at the very low average figure of 100*l.* per ton, the value of the ships saved was above 50,000,000*l.* But these, of course, are not the only factors in estimating the success of the paravane. The moral effect of the loss of these vessels would have been stupendous, disastrous to ourselves and cheering to the enemy, and cannot be assessed, whilst the time and labour spent in replacing these losses augments very considerably their value in wartime.

Before leaving this part of the subject, it should be stated that the paravane installation on Allied war vessels was equally successful. In September, 1918, the U.S.S. South Carolina cut a German mine with her starboard paravane, and in this one act more than justified the whole expense incurred by the U.S. Navy Department in connection with paravanes. It is also on record that another U.S. ship deflected a floating mine which had apparently a long mooring-line attached to it, and so was also saved from destruction.




Although paravanes were not designed to protect ships from floating mines, it is apparent from this incident that if floating mines have a mooring-rope of sufficient length, the paravanes will foul the rope and deflect the mine from the ship's side.

The record from Italy is likewise remarkable. Not only did several individual Italian warships cut mines, but the successful attack on Durazzo was only rendered possible by the vessels being fitted with paravanes. The attacking fleet passed unscathed through two minefields and more than a dozen mines were cut.

These instances could be multiplied many times, but enough has been said to demonstrate amply both the tactical and financial results that are attributable to this remarkable invention.

*Results Obtained by Otters on Merchant Ships.*—The success of the Otter when used as a protection on merchant ships against moored mines is equally striking, and can be well illustrated by the reading of the following letter which is one of several received.

H.M. Hospital Ship Goorkha, Salonika.

"Gentlemen,—I would like to pay a tribute to the efficiency of the Otter gear as fitted to this boat. The last minefield I passed through in daylight, the Otters cut adrift three enemy moored mines (in 15 minutes), which came to the surface just abaft the bridge. In dangerous areas, especially such as some of the pro-enemy waters we have to traverse just now, the Otters are more than ever necessary, and look-outs are placed in Nos. 5 and 6 boats to watch the water surface above the Otters. The patients (who are able) are kept on deck with lifebelts on, and the crew also as far as possible. The tremendous tearing sound and vibration caused by the mine mooring-wire rushing along the Otter towing-wire, does not leave many of the crew in their quarters forward, and is felt quite strongly on the forecastle head. In the event of getting among mines, I see nothing for it but to steer a straight course, full speed if possible, as slowing down too much or stopping brings the Otters to the surface where they are useless, and turning under helm renders the stern liable to strike a mine which the Otters have cut adrift. The very hard steel cutting-teeth in the jaws of the Otter show little or no signs after cutting mine wires, although in one case, portions of the wire were found in the jaws, and in another a length of wire and the depth nipper were brought on board with the Otter. In another instance, the port Otter refused to work and came alongside ship when it was found on hoisting it out of the water that, though it had cut the mine adrift, it had fouled the wire with some anchoring arrangement attached. The wire was cut with an axe and the Otter freed. In most cases the mines cut adrift by the Otters have very shortly afterwards been sunk by gunfire.

in the Mediterranean from June 28 to November 17, the ship steamed 1,594 hours, during which time the Otters were in use 361 hours.

"Yours obediently,
JOHN D. WHITTON."

Efforts were made by the Admiralty Otter Department to obtain accurate returns of the number of merchant vessels which cut mines. These were not very successful, as the following authentic incident will show:—

A coastguardsman was watching a merchant vessel from a shore station through his telescope. It was a calm, clear day and nothing else was visible. Suddenly he saw a black object appear in the steamer's wake. As it had the appearance of a mine a motor boat was sent out to investigate. The surmise was correct. It proved to be a mine which had been cut adrift by the steamer's Otters, but no report of the cutting of that mine was ever received from the steamer.

If out of 180 British warships fitted with the paravane installation 52 cut mines, it would be very interesting to know how many merchant ships cut mines out of the 3,000 fitted with the Otter gear. If the ratio $\frac{\text{mines cut}}{\text{ships fitted}}$ for merchant ships were only one-quarter that ratio for warships, the saving to the nation would be about 100,000,000*l.* sterling's worth of merchant ships and cargoes.

The efficiency of the Otter gear may be proved in another way. In the early days of the German activity in mine-laying, as many as 18 Allied merchantmen were sunk per month by mines alone. At a later date when the mining activity was much more intense the Allied losses dropped to a maximum of three or four per month, and these were in every case ships not fitted with the protector gear. There is, as a matter of fact, no case on record of a merchant ship being hit by a mine when towing the Otter protection. Taking all these facts into consideration, we can leave to the imagination the huge saving to the nation resulting from the widespread adoption of this invention.

*The Paravane Installation for Mine Sweeping Purposes.*—There only remains to be described the paravane installation for mine-sweeping purposes. As already stated, the purpose of this installation was to sweep up mines by means of high speed vessels. It was fitted on destroyers, which because of their shallow draught were not fitted with a protector outfit. In this case the paravanes were towed from the stern. As this entailed a point of tow on deck, the towing wires would in the ordinary way only reach the necessary depth to pick up moored mines at some distance from the ship, and would leave a certain amount of water unswept. To bring the virtual point of tow to the required depth at the stern of the ship, a depressor was employed, the general arrangement being shown in Figs. 7, 8 and 9. The depressor consisted of an egg-shaped body with a plane attached which, lying horizontally in the water, carried the depressor down to the necessary depth. Between the depressor and the vessel was a four-eyed plate to which was attached the depressor towing-wires and the blocks to carry the paravane wires. This type of sweep enabled wide paths to be swept even at such high speeds as 26 knots to 30 knots.

The results of the high-speed sweep cannot be tabulated, as, unlike the paravane equipments, it did not definitely save any vessels from destruction or damage. And although it possibly was not, and could scarcely be, utilised to its full advantage in the Great War, its employment was an interesting development of the original purpose to which paravanes were applied.

*Conclusion.*—As a final summary of the utility of the paravane installations, it can confidently be stated that from all the records available, the Allied countries are indebted to the paravane invention for saving ships and cargoes to the value of approximately 200,000,000*l.* In addition, the number of lives saved must be a very large figure, but has not been computed.

The utmost credit must be given to the inventor, Acting Commander C. D. Burney, C.M.G., R.N., not only for his originality of conception, but also for the indomitable energy he displayed in developing the details and in overcoming the many initial practical difficulties. It has been stated in the July issue of the Journal of the United States Institute in an article by Lieut. Catlin, U.S.N.R.F., that in the early days of the experimental work, the Admiralty became convinced that the device was unworkable and ordered all further work on it to cease. Commander Burney and his friends, however, were convinced of the potentialities of the scheme and, without despairing, swept the immediate difficulties away and were thus given a further opportunity of perfecting what has proved one of the most remarkable and useful inventions of the war.

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SHORTAGE OF LOCOMOTIVES IN SOUTH AFRICA.—There is a continued shortage of locomotives at the coast ports, says *The South African Mining and Engineering Journal*. Only a few days ago at Delagoa Bay there was a demand for 7,000 tons of coal, but only 1,300 tons were available in consequence of the shortage of locomotive power to convey the coal from the Transvaal mines to the coast.

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CAPITAL ISSUES.—The Treasury announce that applications for permission under the Defence of the Realm Regulation 30B to raise capital in this country where the proceeds of the issue are to be applied for capital purposes outside the United Kingdom will in future be dealt with by the Board of Trade. All communications with regard to either new or pending applications should be addressed to the Secretary, Capital Issues Committee, Board of Trade, Gwydyr House, Whitehall, London, S.W. 1.

## FUEL ECONOMY IN THE IRON AND STEEL MANUFACTURE.

*A Report on "Fuel Economy and Consumptions in the Manufacture of Iron and Steel."**

Presented on behalf of the British Association Fuel Economy Committee by Professor WILLIAM A. BONE, D.Sc., F.R.S. (Chairman), Sir ROBERT HADFIELD, Bart., F.R.S., and Mr. ALFRED HUTCHINSON, M.A.

### INTRODUCTION.

DURING the course of its investigations the British Association Fuel Economy Committee made, in the year 1916, certain detailed inquiries, through its Metallurgical Sub-Committee (of which Dr. J. E. Stead, F.R.S., was then the chairman), into the actual fuel consumptions in a number of selected British iron and steel works, in order to obtain reliable data upon which conclusions as to possible future economies might be based.

The method adopted was to ask each of the firms selected to answer a series of carefully drawn-up questions as to their fuel consumptions and arrangements, on the understanding that their replies should be sent for analysis to Professor Bone, as chairman of the General Committee, without any names being disclosed. Accordingly, on receipt of their replies, Professor Bone proceeded to analyse and tabulate the information contained therein, according to a plan whereby the identity of each firm in question was concealed under a distinctive Roman numeral, the key to which has since remained in his exclusive possession. It is therefore to be understood that in no circumstances would he feel at liberty to disclose the identity of any one of the firms concerned, to each and all of whom the committee desires to express its warm thanks and appreciation for their most valuable co-operation in the interests of fuel economy throughout the industry as a whole.

The committee, having thus collected and analysed all this information relating to British practice in the years 1914–15, had next to consider how it might best be published and made generally available in some conveniently summarised form. With the approval of Sir Robert Hadfield, who is now presiding over its carbonisation and metallurgical section, it was decided to confer with the Council of the Iron and Steel Institute, who at once took up the matter, and were good enough to offer to publish the results of the inquiry. They further proposed that this report, together with other contributions, should furnish the basis of a general discussion upon fuel economy at the next autumn meeting. The committee, having unanimously consented to these proposals, authorised this report to be prepared and presented by us on their behalf, and in doing so we desire to associate with it the name of Dr. J. E. Stead, who was so largely responsible for initiating the inquiry.

The prime object of the investigation being to obtain reliable data as to the present state of fuel consumptions and economy in regard to (*a*) blast-furnace practice, and (*b*) steelworks and rolling-mills producing ordinary steel sections, which after all, account for an overwhelming proportion of the total coal used in the production of iron and steel, as distinguished from the subsequent fabrication of these materials into various implements and machines in engineering establishments, the committee decided not to complicate the subject by extending very far their inquiries to the manufacture of crucible and special alloy steels. For in the latter "heat treatment" plays such an essential and prominent part that fuel economy *per se*, although important, must always be regarded as subordinate to the ultimate quality of the product. Dr. Stead, however, obtained some information from two Sheffield firms as to their coke consumptions in the melting of crucible steel; this information is included in the report, because it raises the question of the alleged unsuitability of "by-product" coke for that purpose.

Also in regard to cupola practice in iron foundries, the fact that conditions differ so greatly, according to the type of castings produced, makes the drawing of comparisons or the deduction of general conclusions so difficult that it was deemed inadvisable to include this aspect of the subject in the scope of the inquiry. Moreover, as Mr. H. James Yates, of Birmingham (vice-chairman of the committee) had prepared a valuable memorandum embodying his experience in cupola practice, it was thought better that he should present it on behalf of the committee, as a separate contribution to this discussion, which he kindly consented to do.

### SECTION I.—HISTORICAL.

It may be justly claimed that, for at least three-quarters of a century after James Neilson's epoch-making invention of the use of hot-blast in 1828, British metallurgists led the way in regard to fuel economy in the manufacture of iron and steel. The mere recital of such names as those of Lowthian Bell, Charles Cochrane, Thomas Whitwell, E. A. Cowper and Henry Bessemer, all of whom may be said to have accomplished their principal work within the period 1850 to 1885, is sufficient evidence of the supremacy of British technology in this particular direction during the latter half of the nineteenth century.

*James Neilson.* 1829–33.—As the result of Neilson's application of hot-blast in the smelting of iron at the Clyde ironworks near Glasgow, during 1829–33, the coal consumption per ton of iron produced is said to have been reduced from 8 tons to 1¼ cwt., with cold-blast to 5 tons 3½ cwt. with blast preheated to 300 deg. F. only, whilst with blast at 600 deg. F. it was further reduced to 2 tons 5½ cwt. only.* This wonderful achievement inaugurated an era of continuous progress in fuel economy which has not yet closed.

*Bunsen and Playfair,* 1845.—In 1845 Bunsen and Playfair reported to the British Association at Cambridge the results of their classical investigations on the composition of the gases at various levels in a blast furnace at Alfreton, in Derbyshire. This furnace was 40 ft. high, with a diameter of 11 ft. at the boshes. The fuel charged into it was raw coal (yielding 67·2 per cent. of coke, and 64·5 per cent. of "fixed carbon"), and blast (preheated to 626 deg. F.) was supplied at a pressure of 6·75 in. of mercury through a nozzle 2·75 in. in diameter.

The ore smelted was described as "an aluminous spherosiderite, which is previously roasted so as to free it from moisture and carbonic acid, and by this means is converted into an argillaceous peroxide of iron." Eighty charges were put through the furnace every 24 hours, each consisting of 420 lb. calcined ironstone, 390 lb. coal, and 170 lb. limestone, and from each of which 140 lb. of pig-iron were produced. The coal consumption was therefore as nearly as possible 2 tons 16 cwt. per ton of iron produced, whilst the exit gases were reported to contain:—

$CO_2 = 8{\cdot}370$, $CO = 26{\cdot}846$, $CH_4 = 2{\cdot}536$, $H_2 = 1{\cdot}126$, $C_nH_m = 0{\cdot}112$, $H_2S = 0{\cdot}045$, $NH_3 = 0{\cdot}058$, and $N_2 = 60{\cdot}907$ per cent.

Bunsen and Playfair came to the remarkable conclusion, "that in the furnaces of Alfreton not less than 81·54 per cent. of the fuel is lost in the form of combustible matter still fit for use, and that only 18·46 per cent. of the whole fuel is realised in carrying out the processes in the furnace." They also pointed out that "hot-blast furnaces fed with coal are peculiarly adapted for the economy of gaseous fuel, which may be conducted from the furnace and applied without in any way interfering with its operations . . ."

It is recorded that, as long ago as 1814, such waste gases had been used in France by Mr. Aubertot for making steel by the cementation process and for the burning of bricks; also that Dufaur, in 1837, had drawn the attention of ironmasters to the enormous wastage of energy involved in the then prevalent custom of allowing the gases to burn as they issued from the furnaces. But the publication of Bunsen and Playfair's memoir by the British Association in 1845 put the matter forward in a manner that compelled immediate action. Thus, we find that, in the same year, J. P. Budd, of Ystalyfera, patented a stove for heating the blast by means of the furnace gases, and that some time afterwards he also used them for firing boilers. In 1850, G. Parry introduced at Ebbw Vale the well-known "cup and cone" arrangement for closing the throat of the furnace, so that the gases might be led off and utilised. Two years later, iron ore was calcined by means of the gases at Coltness in Scotland.

*Lowthian Bell,* 1853–72.—It was about this time that, following on the lines of Bunsen and Playfair, Lowthian Bell began, at the then newly-established Clarence Works of Bell Brothers, near Middlesbrough, his investigations upon fuel economy in the blast furnace, which were subsequently published in his "Chemical Phenomena of Iron Smelting" in the year 1872.

The first six furnaces which this firm erected for smelting calcined Cleveland ore were each 48 ft. high, with a capacity of 6,174 cub. ft. When first operated, with a moderately-heated blast, the weekly output was 130 tons per furnace, and the coke consumption amounted to nearly 34 cwt. per ton of iron produced. On increasing the blast temperature, the weekly output rose to a maximum of 220 tons per furnace, whilst the coke consumption fell to about 28·7 cwt. per ton.

In 1865, two new furnaces, each 80 ft. high and 15,000 cub. ft. capacity, were added to the plant, and later on, in 1874, four more of the same height but of capacity 20,200 cub. ft. were built. The beneficial results, in regard both to weekly output and coke consumption, of thus proportionately increasing the furnace dimensions are shown as follows:—

| Year. | Furnace Dimensions. | | | Weekly Output per Furnace. | Coke Consumption per Ton of Iron |
|---|---|---|---|---|---|
| | Height. | Diameter at Bosh. | Capacity | | |
| | ft. | ft. | cub. ft. | tons. | cwt. |
| 1853–61 .. | 48·0 | 16·50 | 6,174 | 130–220 | 34·0–28·7 |
| 1865 .. | 80·0 | 20·50 | 15,000 | 310 | 23·11 |
| 1872 .. | 80·0 | 22·25 | 20,200 | 440–470 | 22·40 |

*E. A. Cowper and Thomas Whitwell,* 1860–5.—Meanwhile, other ironmasters in Durham and Cleveland had been similarly increasing both their furnace dimensions and blast temperatures, thinking that each successive increase in dimensions would result in further fuel economy. In this they were powerfully aided by the independent inventions by E. A. Cowper and Thomas Whitwell (1860–5) of hot-blast stoves fired by the furnace gases on regenerative principles. But their expectations were hardly fulfilled by the performance of two gigantic furnaces, each 103 ft. high and 33,000 cub. ft. capacity, erected at Ferryhill in the year 1868. In that year also, Charles Cochrane, in advocating the use of still higher blast temperatures, had publicly expressed the opinion that "enough heat might be conveyed into the furnace

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* Report submitted at the Sheffield meeting of the Iron and Steel Institute, on Thursday, September 18, 1919.

* *Vide* Professor Thomas Turner's "Iron," second edition, page 20.

with the blast to enable a ton of iron to be produced from Cleveland stone with 13 cwt. of coke."

*Limits of Fuel Economy in the Blast Furnace Defined*, 1872.—Bell, who had been investigating the matter in his laboratory from a fundamental standpoint, was perhaps the first metallurgist to realise the operation of the "law of mass action" in the smelting of iron. This important principle had been enunciated by Berthollet in his celebrated "Essai de Statique Chemique" in 1803, but it had never been generally accepted by chemists until Guldberg and Waage revived it in 1867. Bell at once grasped its importance, and discovered in his laboratory the reversibility of the interactions between carbonic oxide and the oxides of iron at all temperatures in the blast furnace :—

$$Fe\,x\,O\,y + y\,CO = y\,CO_2 + x\,Fe.$$

It was this discovery, and Bell's convincing exposition of it in his "Chemical Phenomena of Iron Smelting," which proved beyond all question that the natural laws governing the reduction of the ore in the blast furnace make it impossible to utilise, within the furnace itself, more than a certain fraction (which Bell seems to have considered as about 53 per cent.) of the total available energy of the coke charged into it. Upon this cardinal fact, which confronts every ironmaster, the whole question of fuel economy in iron and steel works may be said to hinge.

Having satisfied himself of the truth and far-reaching importance of his discovery, Bell proceeded logically to define the practical limits of fuel economy in a Cleveland blast furnace. He clearly saw that there would be certain limiting conditions, both as regards furnace dimensions (particularly height) and blast temperatures, beyond which no further economy in fuel would result; and the Ferryhill experience showed him that, as regards dimensions, the limit had probably been reached. He also considered that it would not be practicable to preheat the blast beyond 1,000 deg. C., and that already, even in 1872, Cleveland ironmasters were nearing the practicable limit of fuel economy in their furnaces.

His main conclusions on the matter may be summed up in the following statements, namely :—

1. That no advantage can possibly accrue from an increase in the height or capacity of the furnace beyond the limits which would permit of the gases leaving the furnace at a temperature of about 300 deg. C., and

2. That the practical limit beyond which the reducing power of the gases cannot be further utilised in the furnace is reached when at their point of exit therefrom, and at a temperature of 300 deg. C. they contain 45 to 50 of carbon dioxide to every 100 of carbon monoxide by volume.

*Bell's Estimate for Limits of Fuel Economy in Smelting Cleveland Ironstone.*—He held that, in regard to Cleveland practice, the limiting furnace dimensions would be a height of 80 ft. combined with a capacity of 16,000 cub. ft., and he expressed the opinion that "taking the ordinary run of Durham coal and Cleveland ironstone, the ironmaster who produces a ton of No. 3 iron with 21¼ cwt. (of coke), with the blast heated to 500 deg. C., may consider himself working very closely up to the limits of economy which are prescribed by the nature of the materials he is operating upon," and that "it is useless to hope to smelt a ton of grey iron from the Cleveland stone yielding 41 per cent. of pig-iron metal with anything notably under 20¼ cwt. of coke."

Reviewing contemporary practice, Bell estimated that by having increased their furnace dimensions and blast temperatures, Cleveland ironmasters had already, by the year 1872, effected a saving equivalent to 1,000,000 tons of coal per annum, exclusive of a further 0·75 million tons which had accrued from their having adopted the practice of using the waste gases from the furnace for preheating the blast, and for raising steam in their boilers to drive the blowing engines. But, as he had stated, they had even then almost reached the practical limit of fuel economy so far as the actual consumption in the furnace itself was concerned.

We have dealt at some length with the history of fuel economy in the blast furnace during the fifty years (1830–79) following James Neilson's inventions, because it is important to show that in those days British ironmasters led the way in the matter.

*Henry Bessemer*, 1856.—Moreover, as regards the conversion of the crude product of the blast furnace into steel, it was Henry Bessemer who, in a paper read before the British Association in 1856, announced to the world his wonderful discovery that this can be effected on a commercial scale simply by blowing air through the molten metal without the expenditure of any additional fuel beyond that required to generate the blast. Indeed, perhaps the most striking feature about Bessemer's process was that the temperature of the bath could be maintained at a sufficiently high degree merely by the oxidation of the metalloid impurities present.

*Snelus*, 1872; *Thomas and Gilchrist*, 1880.—The extension of this "pneumatic" process to dephosphorising iron in a basic-lined converter, which was first proposed by Snelus in 1872, and finally brought to a practical success a few years later by Thomas and Gilchrist, completed a series of inventions which, from the point of fuel saving in the manufacture of steel, have perhaps not been excelled.

*The Brothers Siemens.*—Contemporaneously with these great advances, the brothers Siemens were successfully applying their open-hearth "regenerative" furnace to the manufacture of steel. They first gasified the fuel by partially burning it in a separate furnace, termed the producer, and then preheated both the resulting gas and the air necessary for its combustion to above 1,000 deg. C. by passing each separately through firebrick chequered chambers ("regenerators") which had been previously raised to a high temperature at the expense of the sensible heat in the waste gases from the furnace. The gas and air, thus preheated, were conducted by separate flues to the hearth of the furnace where combustion took place with the production of a high enough temperature to maintain the decarburised iron in the necessary fluid condition for its further refinement. Thus it may be said that, from the labours of all these distinguished investigators during the period 1856 to 1880, inclusive, there emerged the cardinal principles of fuel economy in the manufacture of steel upon which we to-day chiefly rely. Most of the subsequent developments that have been made in this connection have been mainly in details, such as larger furnace dimensions, improvements in mechanical accessories, and a better understanding of the underlying principles of gas-producer practice made possible by recent developments in the science of gas reactions.

*Gayley on the Use of Dry-Blast*, 1905.—The coke consumption in the blast furnace having been brought down, by the year 1875, nearly to the then practicable minimum, little more was accomplished in that direction until James Gayley demonstrated, in the year 1905 at the Etna Works of the Carnegie Steel Company, Pittsburg, how it might be further reduced by the use of dry-blast. Smelting a mixture of Mesabi and Michigan hematite ores containing 53·5 per cent. of iron, with blast at 12 lb. to 15 lb. pressure preheated to a temperature between 750 deg. and 850 deg. F., he showed that by drying the blast until it contained only 1·75 grains of moisture per cubic foot, the coke consumption could be reduced from 2,260 lb. to 1,815 lb. per ton of iron produced, whilst the furnace output was increased. The ratio $CO/CO_2$ in the exit gases fell from 1·70 to as low as 1·25, or much below the "practical limit" of 2·0 assigned by Bell in regard to Cleveland practice.

This remarkable achievement under American conditions of "hard driving" was, in the year 1909, paralleled by the adoption of dry-blast at Messrs. Guest, Keen and Nettlefold's Dowlais works, where, on working for the utmost practicable fuel economy, the coke consumption was reduced from 2,278 lb. to 1,857 lb. per ton of iron produced, whilst the furnace output rose from 2,000 tons to 2,286 tons per week.

No complete explanation has yet been given as to the causes of the considerable economies thus effected, although there are certainly three operative, namely: (1) The increase in the temperature of the zone of combustion in the region of the tuyeres, due to the elimination of water from the blast; (2) the consequent higher temperature at which the mixture of carbon monoxide and nitrogen generated at the tuyeres leaves the zone of combustion—a circumstance which would undoubtedly accelerate its reducing action in passing upwards through the ore in the middle regions of the furnace; and (3) the greater uniformity of working conditions established throughout the furnace by keeping the water-content of the in-going blast constant.

Whilst freely acknowledging the merits of the Gayley system as a possible means of reducing coke consumptions in the blast furnace, the experience of those who have studied the question in its commercial aspects on this side of the Atlantic seems to be that the degree of advantage accruing from its adoption varies considerably according to local circumstances, such, for instance, as (1) climatic conditions, (2) the character both of the ore smelted and of the product aimed at, and (3) the speed at which the furnace is driven. If the moisture content of the atmosphere is normally fairly high, the use of dry-blast is probably advantageous where furnaces are working with high blast temperatures, as in smelting ferro-manganese, ferro-silicon, &c., or producing high silicon iron. The late Mr. T. C. Hutchinson, who went carefully into the question in relation to Cleveland practice, concluded that it would not be "economically wise" to install the Gayley system there, and he doubted whether it would generally be so in regard to British plants as a whole. This opinion is borne out by the experience of three different firms who answered the committee's inquiries on the subject.

Professor Bone, treating of the subject in his book on "Coal and its Scientific Uses," has expressed the opinion that inasmuch as "in a modern steel-producing plant comprising coke-ovens, blast furnaces, steel furnaces, rolling mills, the objective to be aimed at, in the interests of an all-round fuel economy, is such a utilisation of the combined surpluses of coke-oven and blast-furnace gases as will do away with the necessity of gasifying coal in producers, or burning it under boilers, and to use no more fuel than is charged into the coke ovens to make the coke required for the blast furnace, it is obvious that there must be a certain minimum quality of blast-furnace gas which is compatible with the attainment of such an ideal," . . . (and) "a saving of coke in the blast furnace, if accompanied by the production of a gas of less than a certain limiting CO content, might be outweighed by the necessity of having to burn more than the equivalent amount of coal elsewhere on the plant." According to this reasoning, therefore, it would hardly be economical on such a plant to reduce the coke consumption in the blast furnace below the proportion necessary to provide the minimum number of heat units in the outgoing gases necessary to carry out, in combination with those in the surplus coke-oven gas, the operations in the plant as a whole without further expenditure of coal either in gas-producers or under boilers. The question is one involving other considerations than the mere saving of coke in the blast furnace, "and could only be decided after a very careful review of the requirements of such a plant as a whole."*

* The authors desire to express their indebtedness to the courtesy of Messrs. Longmans, Green and Co., in allowing them to make free use of the data and information contained in Chapters XIX and XX (pages 389 to 430 inclusive) of Professor Bone's book.

## SECTION II.—THE ORGANISATION OF FUEL ECONOMY IN A MODERN IRON AND STEEL WORKS.

*Present-day Conditions of Fuel Economy.*—This brings us to the main thesis of our report, namely, that the achievement of the utmost fuel economy in a modern iron and steel works is essentially a matter of the scientific organisation and disposition of the plant as a whole, with a view to utilising to the best advantage, in the steel works and rolling mills, the energy in the surplus blast-furnace and coke-oven gases. For this has been shown to be sufficient, not only for converting molten iron from the blast furnace into steel, but also for rolling the resulting ingots into finished steel sections.

The possibility of attaining such an ideal is primarily due to three great technical developments which have been made since 1880, namely :—

1. In the manufacture of metallurgical coke in chamber ovens with heat recuperation and by-product recovery, which have mainly been due to the efforts of Continental (Belgian and German) chemists and engineers;

2. In the generation of power in internal-combustion engines from cleaned blast-furnace gas, the practical possibility of which was first demonstrated by the late Mr. B. H. Thwaite in 1894–5, and afterwards realised on a large scale by Messrs. Bailly and Krafft, under the leadership of the late Mr. Adolph Greiner at the Seraing works of the Société Cockerill in Belgium; and

3. In methods of cleaning blast-furnace gas (*a*) by water-washing, as in the Thiessen apparatus, or, preferably, (*b*) by electrostatic methods, which have recently been developed in this country.

The economy in fuel which would result from the concentration of by-product coke ovens, blast furnaces, rolling mills, and steel works on one site, coupled with the utilisation of the combined surpluses of coke-oven and cleaned blast-furnace gases, partly in large internal-combustion engines driving dynamos generating electricity for operating the rolling mills and all other machinery on the plant, and partly also to displace producer gas in the steel furnaces and soaking pits, has become manifest during the early years of the present century, largely as the result of Continental experience (*i.e.*, in Belgium, Germany and Austria).

It should here be remarked that the British iron and steel industry has, in this respect, laboured under a disadvantage as compared with its Continental rivals. For whereas most of our smelting plants and ironworks were established before 1880, the modern German industry arose after that period, when it was manifestly the right policy to organise and lay out iron and steel plants with the express purpose of securing all the advantages latent in such a concentration of units as has been indicated. And here, it must be admitted, the German genius for organisation, and for the logical working out of a policy based on ascertained scientific principles, had ample opportunity, which it did not fail to turn to the best advantage. Accordingly it was not surprising to find, during the decade preceding the war, that whilst the newer German iron and steel works embodied in a marked degree, the advantages of concentration and co-ordination of units, under scientific control, the older British plants had to be gradually remodelled, as circumstances permitted, so as to conform, as nearly as possible, to the new conditions. It is, therefore, not necessarily disparaging to British enterprise to have to admit that, since the opening of the present century, the Continental industry has probably secured a lead in regard to fuel economy, because of its comparative newness and superior organisation. At the same time, some of our British undertakings had also shown commendable enterprise in this direction.

*T. C. Hutchinson*, 1910.—Already in 1910, the late Mr. T. C. Hutchinson had satisfied himself, as the result of his experience and investigations at the Skinningrove works, that with a proper concentration and arrangement of the various parts of the producing units "the time would shortly come when ironstone would be brought in at one end of the works and finished steel would be turned out at the other, only such coal being used as was required for the coke ovens to make sufficient coke to smelt the ironstone,"* a declaration which he repeated in the course of the discussion upon Mr. Houbaer's paper at the Brussels meeting of the Iron and Steel Institute in 1913.†

*Mr. Arthur Cooper*, 1912.—Mr. Arthur Cooper had, in his presidential address to the Institute in 1912, expressed his faith in the practicability of the proposition in the following decided terms :—

"During the fifteen years that have passed since 1897, it has been demonstrated beyond all question that both coke-oven and blast-furnace gases can be economically applied, not only as the motive power for driving large engines and for generating electric power, but also as fuel for mixers, open-hearth furnaces, and heating furnaces; and I confidently believe the day is close at hand when in the best-managed works, equipped with modern by-product coke-ovens and blast furnaces, the whole of the converting, heating, rolling and finishing operations will be carried out with no other fuel than their own surplus gases, and that if any of us fail to utilise our resources to the fullest extent, unless exceptionally situated, we may be left in the race."‡

*Professor W. A. Bone*, 1916.—As the result of his association with Mr. T. C. Hutchinson's enterprise at Skinningrove, Professor Bone was enabled to publish, in

* Presidential Address to the Cleveland Institution of Engineers in 1910.

† Journal of the Iron and Steel Institute, 1913, No. II, page 10.

‡ Journal of the Iron and Steel Institute, 1912, No. I, page 47.

1916, a diagram* relative to the concentration and disposition of plant requisite for the production of a ton of finished steel sections from Cleveland ironstone and Durham coke, with the expenditure of no more than 1·6 ton of coal charged into the coke ovens. As this diagram illustrates some of the essential features of such a scheme, it is appropriately appended to this report.

*Mr. Benjamin Talbot, 1917.*—The subject was also dealt with in two reports prepared for the Coal Conservation Committee (1) by Professor Bone on "The Manufacture of Metallurgical Coke," and (2) by Mr. Benjamin Talbot upon "Fuel Economy in a Modern Steel Works Unit, designed for the Heavy Steel Trades."† Mr. Talbot was somewhat more conservative in his estimate of the fuel requirements than Professor Bone, saying (in regard to the production of finished steel sections from British ores) that "although the calculations show that the coal carbonised at the ovens can yield sufficient power for the operation of the works, yet for the sake of safety it is assumed that an exra 2 cwt. of fuel per ton of finished material is required; this added to the 33 cwt. of coal used in the coke ovens gives a total of 35 cwt. as being the total fuel required per ton of finished material." Professor Bone, on the other hand, is convinced that it will ultimately be found that the extra 2 cwt. referred to will not be needed. It is, however, satisfactory to note the close agreement shown by these two reports, between the conclusions arrived at by two entirely independent investigators viewing the problem from somewhat different standpoints.

*The Practical Ideal of Fuel Economy in Steel Manufacture.*—We may therefore feel warranted in regarding the consumption of no more than 1·75 tons of good coking coal per ton of finished steel sections produced as a "practical ideal" for a modern British plant comprising coke ovens, blast furnaces, steel works and rolling mills, properly disposed on one site, and under one control and management.

*Essential Conditions for the Attainment of the Practical Ideal.*—Certain conditions are, however, either essential or desirable for the achievement of such an ideal. Some of the more important of these may be indicated as follows:—

1. By-product coke ovens, blast furnaces, steel works and rolling mills must all be concentrated on one site, and suitably laid out in relation to each other.

2. The by-product coke ovens must be of the regenerative type, so as to yield the largest possible amount of surplus gas.‡

3. The blast furnaces should be fitted with double bells in order to minimise loss of gas. The blast should be regenerated by means of a gas-driven blowing engine. There should also be a proper distribution of the materials in the furnace by means of a suitably dimensioned bell.

4. The gases leaving the furnace should be dry-cleaned, preferably by some electrostatic method, so as to reduce their dust content to about 0·1 gramme per cubic metre. The hot-blast stoves should be heated by this dry-cleaned gas. The gas intended for generating power in gas engines must be further cleaned until its dust content does not exceed 0·015 gramme per cubic metre.

5. There should be separate supplies of surplus coke-oven and blast-furnaces gases throughout the plant; the mixing of two should be carried out at the various points of consumption as required.

6. The gas engines in the power-house should preferably be run on cleaned blast-furnace gas only. For steel furnaces and soaking pits a mixture of blast-furnace and coke-oven gases, in such proportion as will yield a heating gas of between 160 British thermal units and 180 British thermal units per cubic foot, should be used.

7. The rolling mills should preferably be electrically (not steam) driven.

8. There must be scientific management and control throughout the whole heating system by properly-trained fuel technologists, for it is essential that every available heat unit in the plant shall be tracked down and effectively utilised to the best advantage.

*Efficiency of Hot-Blast Stoves.*—With regard to the utilisation of the blast-furnace gas, it was ascertained, in 1915, by Mr. R. S. G. Knight (then a Carnegie scholar working under Professor Bone's direction in the Department of Chemical Technology at the Imperial College of Science and Technology, London) that the actual efficiency of the hot-blast stoves at the Skinningrove works was not more than 66 per cent., and that as much as 29 per cent. of the heat imparted to them was carried off by the chimney gases, which left the system at an average temperature of 366 deg. C.§ It should, however, be remarked that the gas used to fire the stoves in question had not been cleaned; had electrostatic cleaning been introduced, it is probable that the stove efficiency would have been increased to 75 per cent.

*Estimated Heating Value of Combined Surpluses of Blast-Furnace and Coke-Oven Gases from a Cleveland Plant.*—Taking a typical modern Cleveland plant, using 22·5 cwt. of coke per ton of pig-iron produced, Professor Bone has calculated that the heating value of the combined blast furnace and surplus coke-oven gases per ton of iron is equivalent to 15 cwt. of the same coke, and that (assuming a hot-blast stove efficiency of 75 per cent.) no more than 45 per cent. of the blast-furnace gas need be used for generating and heating the blast. The amount of heat in the surplus gases per ton of iron available for the steel works power-house and rolling mills would then be equivalent to that in about 8·5 cwt. of good bituminous coal. And inasmuch as the average efficiencies of gas producers and boilers in steel works is certainly not higher than 75 per cent., the effective coal equivalent of the surplus gases would be at least 11·3 cwt. per ton of iron produced at the blast furnace, and, if properly utilised, this should be sufficient to meet all heat and power requirements in the steel works and rolling mills.

Up to this point, we have not mentioned certain further possible economies which scientific investigation and organisation ought in the near future to effect. We refer to (*a*) the utilisation of the heat in the molten slag from the blast furnace, and (*b*) the recovery of the heat now lost in gas-engine exhausts and steel works chimney gases.

*Recoverable Heat in the Slag.*—The proportional amount of heat carried off in the molten slag from a blast furnace obviously varies, according to the character of the ore smelted and the amount and composition of the slag made per ton of iron produced.

The latent heats of fusion of blast-furnace slags vary between 90 and 120, and their specific heats lie between 0·29 and 0·33. Professor Bone has calculated, in regard to a Cleveland furnace producing 1·75 units of slag per unit of pig-iron, that the heat at present carried off in the molten slag is equivalent to that in about 2·62 cwt. of coke per ton of iron produced, or to about 11·65 per cent. of the heat of combustion of the carbon charged (as coke) into the furnace. In Mr. Walter L. Johnson's experiments at the Clarence Works of Messrs. Bell Brothers, Limited, Middlesbrough, the heat actually recovered, in the form of low-pressure clean steam by a "quenching" method, would appear to have been equal to 5 per cent. of the total heat of combustion of the coke charged into the furnace.*

*Heat Lost in Gas Engine Exhausts and Chimney Gases.*—The sensible heat in the exhaust of a gas engine is probably not less than one-third of that developed in the cylinder; two-thirds of the energy so lost might be recovered by means of a good waste heat boiler. Mr. Knight's experiments at Skinningrove (*loc. cit.*) showed that nearly 30 per cent. of the heat supplied to the hot-blast stove is carried away from it by the waste gases. Such a loss would be, at a very moderate estimate, equivalent to the heat developed by the combustion of 1 cwt. of coke per ton of iron produced, of which at least half should be recoverable, provided that the stoves were worked with dry-cleaned gas.

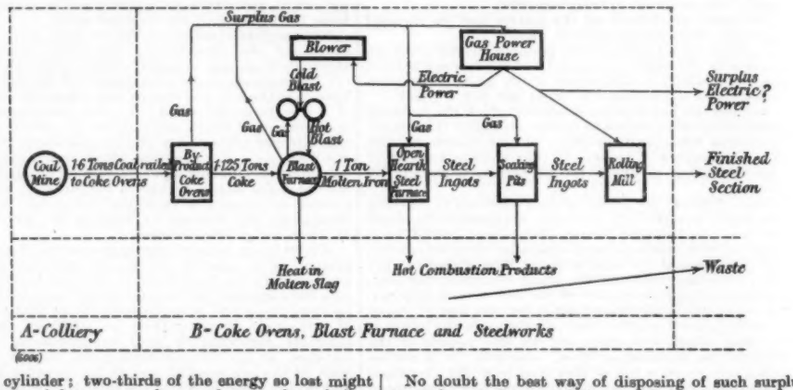
Another large avoidable loss of heat occurs in the waste gases from open-hearth furnaces and soaking pits. The recovery of these lost heat units is a problem which will undoubtedly, in the near future, demand the attention it deserves, and its solution will accelerate the disappearance of the "gas producer" from the "self-contained" iron and steel plants to which this part of our report refers.

*Week-End Gas Losses.*—One further matter calls for remark in regard to what may be termed the "ideal" plant, namely, the important question of how to utilise the surplus blast-furnace and coke-oven gases during the week-end intervals when the steel plant and rolling mills are idle. To provide storage capacity for all the millions of cubic feet of such gases as would be generated in, say, 24 hours in the coke ovens and blast furnaces would probably involve a prohibitive capital outlay. It might, however, be possible to erect gasholders of sufficient capacity to store the surplus coke-oven gas as a reserve against emergencies during the remainder of the week.† The problem is, however, one for which no general solution can at present be suggested, although local solutions of it may in some cases be found.

*Linking-Up of Plants.*—In districts such as Cleveland, where the smelting of plants and steel works are concentrated in a comparatively small area, the conditions are favourable to the success of "linking-up" schemes, as a means of realising more fully the benefits of the policy outlined in this report, by equalising the loads on the power-houses of the various plants during the working week. In this connection, the main transmission system of a public electric power company might be effectively utilised.

*The Problem of the Isolated Blast-Furnace Plants.*—The problem of fuel economy in regard to a blast-furnace plant which is not connected with steel works largely resolves itself into a question of finding some profitable extraneous use, or uses, for the surplus gases and recoverable waste heat which cannot be employed on the plant itself. It is indeed depressing to have to record in this report the confession of one firm that they have 40 per cent. of gas above their requirements which is "allowed to go to waste"; but we fear that a similar admission would have to be made by many other undertakings, if a strict inquiry were instituted into their fuel consumptions.

It will, as a rule, undoubtedly pay any firm to make coke in its own regenerative by-product ovens on a site adjacent to the blast furnaces. In the case of a Cleveland furnace making 1,000 tons of pig-iron per week, and using no more than 22·5 cwt. of coke per ton (which means working under the best possible conditions), it can be shown that the total gas made per hour at the furnaces will be about 1,115,000 cub. ft. at 60 deg. F. and 30 in. barometer. If this were electrostatically cleaned, and used to the best advantage on the plant, half of it should suffice to generate and heat the blast. The potential energy of the other half, if converted into electric power with an overall efficiency of 20 per cent., would be capable of developing 3,350 kw. continuously at the switchboard. The available surplus coke-oven gas would amount to a further 48,000 cub. ft. per hour, or sufficient to generate about 1,150 kw. continuously. Hence the total available power from the combined gases would be about 5,000 kw. continuously. This does not take any account of power derivable either from the stove waste heat or gas-engine exhausts, or yet of the heat carried away in the molten slag and iron, all of which might be turned to profitable use.




(Loss)

No doubt the best way of disposing of such surplus gas and waste heat would be to sell them to an electric power company for conversion into electricity. But if there is no power company near at hand to buy the energy, then it might be used to generate electricity for some electro-chemical process, such, for instance, as (i) the manufacture of nitric acid from the air, or (ii) some electrometallurgical or electrolytic operation. What ought to be realised is that the combined by-product coke-oven and blast-furnace plant is not only an efficient producer of iron, but that it simultaneously, and of necessity, generates a most valuable "power gas," of which the utmost use must be made in the interests of national economy.

## SECTION III.—ANALYSIS OF PRESENT-DAY FUEL CONSUMPTIONS IN IRON AND STEEL WORKS.

Of the 25 firms that responded to the committee's invitation to make detailed returns regarding their fuel consumptions, nine were situated in Durham and Cleveland, four in Lincolnshire, five in the Sheffield area, six in the Midlands (including Salop), and one in Cumberland. The various firms were selected as being representative of their class, with the idea of obtaining from the "average" of the returns a fair idea of fuel consumptions throughout the country as a whole. Twelve of the undertakings owned blast-furnace plants only, nine both blast furnaces and steel works, while the remaining four had steel works only. Altogether, therefore, 21 returns of blast-furnace and 13 of steel-works consumptions were made.

For the sake of convenience the 21 blast-furnace returns will be first of all separately considered in groups according to the quality of iron smelted. Next the returns of the steel works associated with blast-furnace plants will be dealt with. Finally, those from the four steel plants not attached to blast furnaces will be taken. Each individual undertaking will be denoted by a particular Roman numeral, whilst the following alphabetical letters will be used to classify the various works into groups according to the particular brand or quality of iron smelted or used by them, thus:—

B = Basic; C = Cleveland; F = Foundry;
H = Hematite; L = Lincolnshire.

All figures for fuel consumptions will be given in terms of hundredweights of coke or coal per ton of iron or steel produced.

* Royal Institution Lectures on "Fuel Economy and the Utilisation of Coal," 1916.

† Report of Coal Conservation Committee, 1918 (Cd. 9084), pages 79 to 83.

‡ The question of whether or not the ovens should be heated by "dry-cleaned" blast-furnace gas, in order to increase the surplus of the richer coke-oven gas, is an important subsidiary one which is worthy of attention.

§ Carnegie Scholarship Memoirs, 1916, vol. vii, pages 83 to 89.

* Journal of the Iron and Steel Institute, 1914, No. 2, page 98.

† In this connection it may be recalled that, in Mr. Houbaer's valuable paper on "The Utilisation of Blast-Furnace and Coke-Oven Gases in Metallurgy" at the Brussels meeting of this Institute in 1913, it was reported that the Cockerill Company were then erecting at their Seraing works a 50,000 cub. m. (1,650,000 cub. ft.) holder to store their "week-end" make of coke-oven gas.

### A.—Blast-Furnace Returns.

The quality or brands of iron smelted at the 21 blast-furnace plants in question were :—

| — | C. | L. | F. | B. | H. | Cold-Blast. |
|---|---|---|---|---|---|---|
| Total number of plants making returns .. | 7 | 4 | 2 | 4 | 6 | 1 |
| Number of these attached to steel works .. | 3 | 2 | 0 | 4 | 2 | 0 |

#### First Group.—Plants Smelting Cleveland Ironstone.

Returns were forthcoming from seven blast-furnace plants smelting calcined Cleveland ironstone with Durham coke. Three of these plants were attached to steel works. The fuel consumptions are tabulated as follows :—

Table I.

| Firm No. | Fuel Consumption. Coke at Blast Furnace. | Coal or Coke Breeze at Calcining Kilns. | Other Fuel. | Estimated Heat Losses* at Bells. | Stoves. | Boilers. |
|---|---|---|---|---|---|---|
| I. | 21·0 | 4·5 | 0·10 | 1·65 | 3·7 | 5·4 |
| II. | 24·0 | 1·4 | 0·75 | 3·0 | 2·5 | 8·0 |
| III. | 23·0 to 26·0 | 3·0 to 5·0 | 0·50 | 0·6 | 8·2 | |
| IV. | 24·8 | 3·0 | — | 8·0 | 18·0 | |
| V. | 24·0 | 2·2 | — | 0·6 | 8·2 | |
| VI. | 23·0 | 2·0 | 0·96 | 1·0 | 3·0 | 7·0 |
| VII. | 22·9 | 3·46 | | 7·5 | 8·0 | |

* As calculated and returned by each firm in question, but expressed as a percentage of the total heat of combustion of the coke charged into the furnace.

*Remarks.*—1. The average coke consumption in the blast furnace for the seven plants in question is, as nearly as possible, 23·5 cwt. per ton of pig-iron produced. If due allowance be made for the undoubted deterioration both in the quality of Durham coke and in the iron content of Cleveland ironstone during the past fifty years, the figure would appear to be near the "practical limit" assigned by Lowthian Bell in 1872 for the then Cleveland conditions. It is indeed remarkable that Bell's prediction should have been so nearly fulfilled.

2. Assuming that a good Durham coking coal (dry) yields, in by-product ovens, on the average 72 per cent. of coke for the blast furnace, the corresponding amount of dry coal charged into the coke ovens would be $23 \cdot 5 \times \frac{100}{72} = 32 \cdot 65$ cwt., or, say, 1·65 tons. The "surplus" coke-oven gas obtained would be 8,000 cub. ft. of gross calorific value 485 British thermal units per cubic foot. The potential energy in this surplus gas would therefore amount to 3,880,000 British thermal units per ton of iron produced in the blast furnace.

3. The average amount of other fuel (small coal, coke breeze, &c.) used for calcining and other purposes in these plants would appear to be almost 3·5 cwt. per ton of iron produced. If, for statistical purposes, this is taken as half coke breeze, and half small coal whose "fuel value" is only 80 per cent. that of a coking coal, the total dry "coking coal" consumption per ton of iron produced would be 36·5 cwt. (1·825 tons), the "surplus" gas from which would amount to about 9,000 cub. ft.

4. The estimate made by the firms of heat losses at bells, boilers and stoves on their plants varied between 9 per cent. and 26 per cent. of the total heat of combustion of the coke charged into the furnace. The average figure was as nearly as possible 13·5 per cent. It is difficult, in the absence of more complete data and further detailed investigation, to criticise these figures. On general grounds, however, where steam engines are used to generate the blast, and the distribution of the blast-furnace gas is approximately (of the order) 50 per cent. to the boilers, 30 per cent. to the stoves, and up to 20 per cent. as surplus, it is difficult to see how the combined losses at the boiler and stoves could be much less than 15 per cent. of the total heat of combustion of the coke charged into the furnace. The total losses at the bells, stoves and boilers could hardly be less than 17·5 per cent. and might be as high as 20 per cent. This estimate applies, of course, to the average present-day conditions on these plants, and not to the ideal state of things set forth in the preceding section of this report.

5. Several firms supplied details as to the temperatures and percentage compositions of the chimney gases from their stoves and boilers, from which the following may be quoted as representative :—

| | Boilers. | | | Stoves. | | |
|---|---|---|---|---|---|---|
| $CO_2$ .. .. | 11·90 | 15·0 | 15·1 | 16·75 | 24·0 | 16·35 |
| CO .. .. | nil | 1·5 | nil | nil | nil | nil |
| $O_2$ .. .. | 10·40 | 7·5 | 8·3 | 7·10 | 2·0 | 7·60 |
| $N_2$ .. .. | 77·70 | 76·0 | 76·6 | 76·15 | 74·0 | 76·05 |
| | 100·0 | 100·0 | 100·0 | 100·0 | 100·0 | 100·0 |
| Temperature, deg. F. .. | 735 | 550 | — | 450 | 350 | — |

In one other case the average composition and temperature of the combined chimney gases from boilers and stoves was given as follows :—

$CO_2 = 21 \cdot 0$; $O_2 = 3 \cdot 5$; $N_2 = 75 \cdot 5$.
Temp. = 520 deg. F.

6. On only two of the seven plants were gas engines used for generating the blast; the other five used steam engines. In four of the latter cases the exhaust steam was being utilised to generate electric power.

7. In no case was the blast-furnace gas for either stoves or boilers being cleaned.

8. In only one case had any attempt been made to utilise the heat in the molten slag from the plant.

9. In no case had "dry" blast been used. Two firms stated that the working of their furnace was rather more economical during the summer than during the winter months.

#### Second Group.—Plants Smelting Lincolnshire Ores.

Of the four firms that made returns, two had steel plants attached to their blast-furnaces. In two cases slack coal was used for calcining the ore; another firm used gas for this purpose; whilst in the fourth case the ore was charged into the furnaces in its raw state. In two cases the furnaces were fitted with double bells. No estimates were forthcoming of the heat losses at either bells, stoves or boilers, although particulars of the temperatures and compositions of the chimney gases were given in all cases. One firm was using gas engines for generating the blast; another was using both gas and steam engines. The remaining two used steam engines only, although in one case the exhaust steam was being used to generate electricity by means of low-pressure turbines. One firm reported having experimented on one furnace with dry-blast without finding any advantage as regards fuel economy. With regard to gas cleaning, one firm cleaned all the gas required for the stoves as well as for driving the blast engines and generating power; another cleaned it for gas engines and soaking pits, but not for the stoves. The other two firms did not clean the gas at all. The fuel consumptions per ton of iron produced were as follows :—

Table II.

| Firm No. | Coke at Blast Furnace. Cwt. | Slack Coal for Calcining the Ore, &c. Cwt. |
|---|---|---|
| VIII. | 32·0 | Nil. Gas used. |
| IX. | 30·0 to 33·0 | Nil. Raw stone charged. |
| X. | 34·0 | 4·0 |
| XI. | 33·0 | 0·75 |

The average coke consumption in the blast furnace is thus seen to be about 33 cwt. per ton of pig-iron produced, a notably higher figure than the average already shown for Cleveland plants. Assuming the coke to have been manufactured in regenerative by-product ovens from a Yorkshire coal yielding, in the dry state, 70 per cent. of coke, the corresponding dry coal consumption at the ovens would have been 47 cwt., *i.e.*, 2·35 tons. The

*Composition of Waste Gases from Boilers and Stoves.*

| — | Waste Gases from Boilers. | Stoves. | Stoves. | Combined Chimney Gases for Boilers and Stoves. (1) | (2) |
|---|---|---|---|---|---|
| $CO_2$ .. .. | 11·8 | 20·3 | 11·7 | 18·4 | 10·0 to 15·0 |
| CO .. .. | 2·2 | 0·8 | nil | nil | — |
| $O_2$ .. .. | 6·2 | 1·5 | 5·6 | 4·4 | 5·0 to 7·0 |
| $N_2$ .. .. | 78·8 | 77·4 | 82·7 | 77·2 | 76·0 to 78·0 |
| | | | | Boilers. Stoves. | |
| Temp., deg. F. | 1,040 | 735 | — | 1,270 800 | 570 to 930 |

available "surplus" coke-oven gas from this would have been 11,750 cub. ft. of total potential heating value = 5,700,000 British thermal units per ton of iron produced. Such a surplus, in combination with the surplus gas from the blast furnace, ought (if economically used by the best methods) to be more than sufficient to convert the molten pig-iron into finished steel sections without any further fuel. Data as to the temperatures and percentage compositions of the waste gases from boilers and stoves are given in the preceding column.

#### Third Group.—Plants Situated in the Midlands making chiefly Foundry or Basic Iron.

Of this group of seven plants, Table III, four smelted basic iron for conversion into steel in adjacent open-hearth furnaces; another smelted foundry iron only, whilst a sixth made "cold-blast" iron.

None of these firms returned any detailed estimates of the total heat losses at bells, stoves and boilers, although No. XV stated that their losses at the stoves were 40 per cent. and at the boilers 57 per cent. The following information was given in regard to temperatures and percentage compositions of the waste gases from stoves and boilers.

| — | Composition of the Waste Gases from Stoves. | Stoves. | Stoves. | Boilers. | Boilers and Stoves. |
|---|---|---|---|---|---|
| $CO_2$ .. .. | 11·0 | 19·5 | 20·6 | 15·4 | 10·6 |
| CO .. .. | nil | 1·0 | — | 2·4 | nil |
| $O_2$ .. .. | 5·0 | 1·0 | 1·8 | 4·4 | 9·2 |
| $N_2$ .. .. | 84·0 | 78·5 | — | 77·8 | 80·2 |
| Temp., deg. F. | 600 | 280—450 | 536 | 640 | 500 |

#### Fourth Group.—Plants Smelting Hematite Ores.

Six plants smelting hematite ores made returns, of which five (Nos. II, V, VI, XIX and XX) were localised in the Cleveland district, the remaining one (No. XXI) being in Cumberland. The coke consumptions in the blast furnace were as follows, no other fuel being used except a small amount of coal for locomotives, &c. :—

| Firm No. | II. | V. | VI. | XIX. | XX. | XXI. |
|---|---|---|---|---|---|---|
| Cwts. Coke per ton of iron | 22·0 | 21·0 | 20·0 | 20·0 | 21·0 | 24·0 |

Of these plants, Nos. II, VI and V were attached to steel works, and the remainder not. Other information respecting Nos. II, V and VI has already been included in Group I. The remaining three plants had steam-driven blowing engines. In the case of No. XX all the exhaust steam was used by a power company for generating electricity, and in the case of No. XXI it was used for heating the boiler-feed waste. No. XIX reported that "a very small proportion of the exhaust steam was used for heating the boiler feed; some of the engines have condensers and others exhaust into atmosphere." None of the three firms in question gave any particulars about the temperatures and compositions of the waste gases from their stoves and boilers; two of them said that they did not know what their heat losses were. No. XXI stated that they have a 40 per cent. excess of gas above their requirements which is "allowed to go to waste." In no case had any attempt been made to utilise the heat in the molten slag or iron. The average coke consumption for the six plants in question was 21·33 cwt. per ton of iron produced; this would be equivalent to 30 cwt. of (dry) Durham coal carbonised in by-product ovens.

Table III.

| Firm No. | Location. | Grade of Iron Made. | Total Fuel at Blast Furnace. | Other Fuel. | Remarks. |
|---|---|---|---|---|---|
| XII. | S. Yorks. | Basic for steel works | cwt. Coke = 28·0 | cwt. nil | (a) Furnaces have double bells; (b) gas-driven blowing engines used; (c) surplus gas burnt under water-tube boilers to generate steam for rolling mills. |
| XIII. | Notts. .. | No. 3 Foundry | Coke = 13½ Coal = 28½ | Cannel = 2 Slack = 1½ | (a) Furnace tops are open; (b) dry-blast tried for twelve months, but although output increased by 15 per cent. no fuel economy resulted. |
| XIV. | Notts. .. | Basic for steel works | Coke = 24·5 | nil | Steam-driven blowing engines. |
| XV. | Salop .. | Staffordshire | Coke = 26·5 | Small amount of coke-breeze for calcining | Steam-driven blowing engines (compound condensing). |
| | | Basic for steel works | Coke = 29·0 | | |
| XVI. | Salop .. | Basic for steel works | Coke = 20, to 21, with 36 per cent. of iron in burden Coke = 26 to 27, with 27 per cent. of iron in burden | Nil. Apart from locos. | (a) Loss at bell = 5 per cent. of coke charged; (b) steam-driven blowing engine; (c) use of dry-blast saved 3 per cent. to 3·5 per cent. of fuel, but not sufficient to pay interest and depreciation on plant. |
| XVII. | — | Cold-blast iron | Coke = 24·72 | Small coal used for calcining | Furnaces have open tops. |
| XVIII. | — | — | Coal = 29·24 Coke = 2·54 | nil | — |

*Summary.*—1. Leaving out of account the two plants where the fuel charged into the blast furnaces was a mixture of coal and coke, we obtain as nearly as possible the following average figures for coke consumptions in

the furnace per ton of iron produced, and their coal equivalents :—

| Quality of Iron. | Cleveland. | Lincolnshire. | Midlands. Basic. | Hematite. |
|---|---|---|---|---|
| Number of plants averaged .. .. | 7 | 4 | 4 | 6 |
| Average coke consumption .. cwt. | 23·5 | 33·0 | 26·0 | 21·33 |
| Average coal equivalents .. cwt. | 32·65 | 47·0 | 37·0 | 30·0 |

These figures do not, of course, include any allowance for small coal or coke breeze that may be used in calcining the ores, or for the works locomotives, &c.

2. Of the 21 firms included in the returns only three had their furnaces fitted with "double bells," whilst two of them worked with open tops.

3. Only five of the firms used the furnace gases in internal-combustion engines for generating the blast; the remaining 16 all used steam-driven blast engines. Of the latter, eight used their exhaust steam (or the greater part of it) for generating electricity in low-pressure turbo-alternators; other four used it for heating the boiler-feed water. In three of the remaining cases the steam engine was described as "compound condensing."

4. From such details as were given for the temperatures and compositions of the waste gases from the gas-fired boilers, it is evident that the heat losses were considerable, and the efficiency of steam-raising low.

5. As a rule better combustion of the furnace gases was obtained in the stoves than in the boilers, though here again, in some cases, far too great an excess of air was being used in burning the gas. In only one case was the gas for the stoves cleaned.

6. An unsatisfactory feature about the returns was that at least half of the firms apparently had no data sufficient to enable them to estimate, even approximately, their heat losses at the stoves and boilers, whilst four of them confessed to having no data whatever as to the temperatures and compositions of their chimney gases.

7. Apparently only one firm had made any attempt to utilise the heat in the molten slag from the furnaces.

8. Three of the firms had either experimented with or adopted "dry-blast." Of these two reported that no fuel economy had resulted (though one of them states that the furnace output had increased by 15 per cent.), whilst the third had found a saving of 3 per cent. to 3½ per cent. in fuel, which, however, was insufficient to pay interest and depreciation upon the plant required to dry the blast.

9. The general impression conveyed by the results as a whole is that, in most cases, there are considerable margins for economising fuel on British blast-furnace plants, chiefly in the direction of (*a*) reducing losses at the bells, (*b*) improving the utilisation of that portion of the gas which is used for heating the blast, (*c*) substituting gas-driven for steam-driven blast engines, (*d*) utilising the heat carried away in the molten slag, and (*e*) instituting a more systematic fuel control throughout the plant as a whole.

(*To be continued.*)

## FUEL ECONOMY IN CUPOLA PRACTICE.*

By H. JAMES YATES (Vice-Chairman), on behalf of the British Association Fuel Economy Committee.

FUEL consumption in cupolas is found to depend on several factors. The heat developed is employed in the following manner :—

1. For melting the iron and fluxing the impurities.
2. For providing the necessary extra heat in the iron to enable it to continue sufficiently fluid to make satisfactory castings while being carried from the cupola to the moulds—often a considerable distance.
3. To make good the heat losses :—
   (*a*) From the casing by radiation.
   (*b*) Due to sensible heat in the waste gases.
   (*c*) Undeveloped heat in the unburned carbonic oxide.

Of these, No. 2 may seem unnecessary to mention apart from No. 1 because, of course, the ultimate object of all cupola melting is to obtain good castings; but it is now mentioned separately because unless it is taken into consideration a comparison of results obtained in different foundries is impossible. A foundry making light castings requires much hotter iron than one employed on heavier and rougher work. Similarly, a large foundry requires hotter iron than a small one on account of the longer transport from the cupola to the moulds. As a consequence, the fuel expenditure per ton of iron melted is bound to be more for the light casings than for the heavy, and more in the case of the large foundry than the small one. As an example of this, a foundry making both light and heavy castings gave some years ago figures per ton of iron melted as 2 cwt. 2 qr. 4½ lb. coke for the light, and 2 cwt. coke for the heavy castings.

It will be most convenient to deal first of all with No. 3.

(*a*) *Loss by Radiation.*—As the ratio surface : capacity diminishes with increasing diameter, it is advantageous to build wide cupolas, except in so far as the diameter is limited by considerations of blast penetration and is determined with a due regard to the diameter : height mentioned below. This loss by radiation is of small importance compared with losses (*b*) and (*c*).

(*b*) *Sensible Heat in the Waste Gases.*—The gases leaving the combustion zone do so at a high temperature, and the descending charge should be caused to take up as much of their heat as possible, because any heat not so taken up is lost to the cupola. To prevent this loss it is necessary to have as many contacts as possible, per unit time, between the hot gases and the charge, for this is the condition under which the gases most readily part with their heat. In a high and narrow cupola the path of the gases is longer and their velocity greater, and for this reason such a form of cupola is preferable; the ratio diameter : height should therefore not fall below a certain minimum. In this connection it should be noted that the employment of the old-fashioned wasteful cupolas of low and wide form was occasioned by the necessity of keeping the charging-door as near the level of the shop as possible. With the development and adoption of lifts there is no longer any reason for continuing this practice. In this connection it is necessary to ensure the avoidance of bad arrangement of the charge or its improper settling in the cupola, both of which allow hot gases to get away without coming properly in contact with the charge, and thus without giving up their heat. This is further mentioned in (*c*).

(*c*) *The Undeveloped Heat due to Unburned Carbonic Oxide.*—There is no need to emphasise the obvious loss of heat when carbonic oxide escapes at the furnace throat. It represents the loss of, roughly, two-thirds the heating value of the carbon consumed on its formation. It is impossible to ensure that no carbonic oxide shall be lost, but any cause tending to increase the amount of the loss should be carefully minimised, or if possible eliminated. Such causes are : (i) Lack of adequate blast, (ii) badly arranged charges owing to irregularities in charging, or to projections in the lining upsetting the proper settling of the charge, thus allowing, in greater quantity, air to make its way up one part of the furnace than another, or (iii) improper distribution of the air at the tuyeres with the same result as in (ii), and possibly with the further result that the carbonic oxide is not burned, owing to its being already cooled below the ignition temperature before it receives the air necessary for its further combustion.

Dealing with 1 and 2, there are certain points in cupola construction the effect of which has to be considered.

*Tuyeres.*—Much time and thought have been given to the number, position, and shape of the tuyeres. It is often found that on investigation the results obtained by special shapes, &c., do not justify the hopes of their introducers. The general principle which emerges from the various claims made appears to be only that sufficient area of tuyere must be provided, and that as long as the ratio tuyere-area : cupola-area is kept about a certain figure, the results obtained with one or more rows of tuyeres one above another yield no advantage in the ordinary way, provided at least four to six tuyeres are used. The advantage of more than one row appears to be simply that, in case the capacity of the cupola is increased by reducing the thickness of lining, the necessary increased supply of air can be provided for the heavier output.

*Furnace Shape.*—The usual shapes are (1) those of equal diameter all the way from baseplates to charging door, (2) those with smaller diameter from baseplate to a certain distance above the tuyeres. For small cupolas there does not appear to be a great deal to choose between these shapes. In large cupolas, however, the second shape appears to be better for several reasons, viz. :—

The coke bed is smaller.

The blast can get more easily to the centre.

The hot gases ascending from the combustion zone are better distributed in the furnace and less likely to make their way up the sides of the charge.

*Manipulation.*—Charging is done in layers starting from the bed, which must extend 18 in. to 24 in. above the tuyeres; above this in rotation are placed pig, scrap, coke and limestone. It is necessary to find by experiment the correct weights for the most economical working. As the bed is necessarily about the same weight whatever the length of blow, it follows that it is more economical to run longer blows than shorter ones. The coke charges should be just sufficient to bring the bed to its former level after melting the previous iron charge. Experiments may with advantage be made in reducing the coke charge till the best results are obtained, as an excess of coke not only reduces the economy of the furnace generally, but also the speed and regularity of melting in particular.

*Use of Kindling Tuyeres.*—In many foundries the practice is to reject the first iron because of its being too cold. This waste may be eliminated by the use of a kindling tuyere placed low down near the sand bottom. This heats up the coke so that the first few hundredweight of iron are not chilled. With the cupola of which particulars will be given presently, although very hot iron is required because of the lightness of the castings, no iron has ever to be rejected from this cause. After a bogie or so of iron has been drawn off, the kindling tuyere is shut off and plugged.

To put the matter briefly, there are four distinct advantages gained by using such kindling tuyers, namely :—

(*a*) Hotter iron is obtained at the beginning owing to its having to pass through a deeper bed of glowing hot coke. When the kindling tuyere is used properly, all the coke from the bottom up to the melting zone is at white melting heat. The iron on passing through this gathers heat all the way down on its progress to the tapping-hole. On account of the clean condition of the cupola at this stage the iron is probably hotter than any which may be run at any later stage during the day. When the kindling tuyere is not used only the part of the coke bed above the ordinary tuyere is at white heat, and the part of the bed between the tuyere and the bottom is comparatively cold. The iron on its way down through the bed gathers heat until it reaches the tuyere, after which it has to give up heat to the colder part of the coke bed. Under these conditions the first iron melted reaches the bottom almost too cold to run and certainly too dull for any but heavy castings.

(*b*) The iron being hotter from the first gives cleaner and better tapping holes and removes the risk of iron solidifying in them. The condition known in the trade as at "iron hole" is much dreaded by the furnaceman. The iron plugs formed in the holes have to be driven out, and in doing this the clay may be cracked and broken, and the holes made too large. When this happens, it is difficult, if not impossible, to keep back the slag, and as the slag is usually basic in character it fluxes-out the holes and there is a danger of the whole front being melted out.

(*c*) Another advantage of using a kindling tuyere is that when the ordinary tuyeres are put to work they start blowing on coke heated to a very high temperature, and are not so likely to blow cold and form the long "snouts" or projections which so often give trouble by preventing the coke from getting near the tuyeres, a condition which invariably results in "bridging" and the production of cold iron.

(*d*) In many cupolas the bottom is so cold and damp that the first iron is chilled and the carbon is arrested in cooling, with the result that the castings have a surface lining of white iron and are quite useless for machining or filing. Such castings might readily destroy or damage expensive tools. When the kindling tuyere is used the bottom and sides of the cupola, as well as the coke bed, are so thoroughly heated that the danger of producing white hard iron is completely removed. A nice grey soft iron, easily filed and machined, can be run at the first as well as at any time of the cast, if this method is applied.

It is a good plan to reduce the blast pressure and the charge of coke near the end of the blow : this saves coke and also the linings, which latter are often badly damaged towards the end of the blow.

The following particulars give the results obtained with a furnace—one of several—the records of which have been drawn upon over a period of fifteen years. In 1901 the average output given was 7·5 tons per hour, with a consumption of 2 cwt. 2 qr. 6½ lb. of coke per ton; gradually this was improved until in 1912 the output was 10·8 tons per hour, for a consumption of 1 cwt. 2 qr. 23 lb. coke per ton.

At a later period, to increase this output, the diameter both at the charging door and at the tuyeres was increased as was also the tuyere area. The result was an output of 14·3 tons per hour, with a coke consumption of 1 cwt. 3 qr. 16 lb. per ton of iron. Subsequently, when this rate of output was reduced to 12·8 tons per hour, the coke consumption fell to 1 cwt. 3 qr. 4 lb. per ton. This appears to show that for every cupola there is a certain output per hour at which maximum economy in coke consumption is attained. It may be stated that while any increase of output beyond this is obtained only with an increase in coke consumption per ton, yet it may pay to "force" the cupola to give such an increased output rather than to build a small cupola as an auxiliary. This is illustrated by reference to the case of a small cupola in which, with an output of 3·12 tons per hour, the coke consumption was as high as 2 tons 0 cwt. 3 qr. per ton of iron melted.

It must be distinctly understood that the foregoing figures apply exclusively to cupolas engaged on light castings, mainly from ¼ in. to $\frac{1}{16}$ in. thick. Many thousands of these are only of a weight of 2½ lb. per square foot, and the total number of such castings runs into a good seven figures per annum. Further, these cupolas are only run continuously for the afternoon, whereas a whole day's run each time would doubtless reduce somewhat the rate of coke per ton of iron.

Turning to heavy castings, it is much more difficult to get regular figures, because usually foundries engaged on heavy works also make much lighter castings as well, and their records are accordingly difficult to analyse. In general, the consumption of coke per ton of iron melted varies from—for exceptionally heavy work—1 cwt. 2 qr. to 3 cwt. 3 qr. where the castings vary considerably in weight.

Generally, it may be safely stated that in large foundries doing mixed work (as most of them have to) the average consumption of coke approximates nearly to 2 cwt. per ton iron. It is very seldom that such regular working on one particular class of castings is found as that quoted above for those cupolas doing light castings.

The cupolas engaged on light castings and mentioned in the foregoing, show the following ratios :—

| | | | |
|---|---|---|---|
| Area at tuyeres. Area of tuyeres .. | 4·3 | 5·4 | 5·8 |
| Height from tuyeres to charging door. Diameter at tuyeres | 3·8 | 2·8 | 5·3 |
| Iron. Hours of blast (tons) | 10·8 | 14·3 | 3·12 |
| Total coke .. .. | cwt. qr. lb. 1 2 23 | cwt. qr. lb. 1 3 16 | cwt. qr. lb. 2 0 3 |

NON-FERROUS METALS.—The following particulars are published of the stocks (exclusive of old metal and scrap) in this country in possession of the Minister of Munitions on September 1, 1919: Copper, 28,049 tons; spelter, G.O.B., 20,041 tons; spelter, refined, 10,963 tons; aluminium, 10,232 tons; soft pig lead, 84,057 tons; nickel, 2,374 tons; antimony regulus, 3,386 tons. A proportion of the above stocks is already sold to the trade for forward delivery.

* Paper read before the Iron and Steel Institute, at Sheffield, on Thursday, September 18, 1919.